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EVALUATION OF NIGERIAN FOODSTUFFS

by



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A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Evaluation of Nigerian Foodstuffs" submitted by Etim Jonathan Orok, B.Sc., in partial fulfillment of the requirements for the degree of Master of Science.



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ABSTRACT

Three Nigerian foodstuffs, peanut meal (groundnut cake) [PNM(Nig)], yellow corn (maize) [C(Nig)], and guinea corn (sorghum) [GC(Nig)] were evaluated chemically and biologically, using weanling Sprague-Dawley rats. These foodstuffs were compared with two Canadian foodstuffs, soybean meal [SBM(Can)] and corn [C(Can)]. The premise for the study was that knowledge of the nutritive value of Nigerian foodstuffs would permit their optimum inclusion in animal diets. The enhanced animal production which might result could help solve the protein malnutrition problem existing in Nigeria.

The treatments consisted of seven isocaloric (3,600 kcal/kg) diets upon which were superimposed three (20, 16 and 12%) protein levels. On the basis of energy and protein sources and amino acid supplements, these diets were C(Can)-SBM(Can), C(Nig)-SBM(Can), GC(Nig)-SBM(Can), C(Can)-PNM(Nig), C(Nig)-PNM(Nig), GC(Nig)-PNM(Nig) and C(Can)-PNM(Nig)-DL-methionine and L-lysine. Chemical evaluation of the foodstuffs consisted of proximate and amino acid analyses.

At the start of the experiment, 8 representative rats (4 males, 4 females) were killed and proximate analyses determined on whole carcasses to estimate the composition of the rats at the beginning of the experiment. The experimental period was 4 weeks during which live-weight gain, food consumption and efficiency of food conversion were measured weekly. In the last week of the experiment, 3-day energy and nitrogen (N) digestibility and retention studies were conducted on males only. Proximate analyses on whole carcasses were determined for indivi-

dual rats. Biological data from the 7 dietary energy-protein source combinations, three protein levels and two sexes were subjected to analyses of variance.

PNM(Nig) was lower than SBM(Can) in lysine, threonine, valine, alanine, leucine and isoleucine, but about 58% higher in arginine and about 15% higher in crude protein. PNM(Nig)-supplemented diets gave significantly lower ($P \leq 0.01$) liveweight gains (34.8 g) and more fat (24.6%) and less lean (61.4%) in the carcasses than SBM(Can)-supplemented diets which gave 48.4 g, 20.8% and 65.5% respectively. There were interactions between energy and protein sources. Supplementation of C(Can)-PNM(Nig) diets with DL-methionine and L-lysine did not give any significant response. Protein level exerted different effects on different traits. However, 16% dietary protein level was generally the best of the three protein levels used in this study. Males excelled female rats in most of the traits measured. Carcass N as determined by analyses for each rat was expressed as a percentage of the calculated N retention. This ratio averaged only 40% for all diets suggesting that N retention data do not give an accurate measure of actual N in the carcass.

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INTRODUCTION

Nigeria is a developing country and the most populous in Africa. It has an area of 924,626.43 square kilometers (357,000 square miles), a population of 56 million (Anonymous, 1969) and lies wholly within the tropical zone, enclosed approximately by latitudes 4° and $14\frac{1}{2}^{\circ}$ north of the equator and longitudes 2° and 15° east of the Greenwich Meridian. As in other developing countries, the diets of most Nigerians are inadequate in proteins, especially animal proteins. Her per capita consumption of proteins, averaging 51 g per day (Oyenuga, 1967) is below the average 58 g per day for all underdeveloped regions (Food and Agriculture Organization, 1965). The Food and Agriculture Organization (FAO) estimates that Nigeria's population will increase by 55% between 1963 and 1980 (FAO, 1965). This will accentuate the protein malnutrition problem.

Nigeria produces a wide variety of crops such as corn, sorghums, peanuts, soybeans, oil palms, coconuts, cocoa and rubber, the by-products of which could provide food for animal production. In addition, there are large deposits of limestone and petroleum. These products or their by-products could also facilitate animal feeding. As observed by Oyenuga (1967), the low level of animal production in Nigeria is therefore not due to lack of natural resources, but to failure to direct these resources to efficient animal production.

A serious limitation to animal production in Nigeria at present is the high cost of commercial feeds. In 1970, for example, the average

cost of commercial feeds was about 15.4¢ per kg¹ compared with about 7.7¢ per kg² for Alberta, Canada. The absurdity of the situation is obvious when one considers that the per capita income for Nigeria in 1966 was only \$76 against \$2,677 for Canada (United Nations Organization, 1970). If Nigerian farmers are to feed their animals properly, feed costs must be substantially reduced. This will require a thorough assessment, not only of the familiar foodstuffs, but also of the potential ones which at present are waste products of agricultural or other industries. Knowledge of the nutritive value of Nigerian foodstuffs would facilitate their use in the formulation of economical animal diets. Moreover, if some of the existing industrial waste products, such as cocoa husks proved to be nutritionally useful, their incorporation into animal diets would substantially reduce feed prices.

A pilot effort to provide information on Nigerian foodstuffs was made by Oyenuga (1955) in a book entitled "Nigeria's Foods and Feed-stuffs." Subsequent editions (1959, 1968) were considerably revised. The 1968 edition contains extensive reviews of literature including chemical analyses related to foods and foodstuffs occurring in Nigeria. Examination of the three editions indicates a need for more information on Nigerian foodstuffs, especially with regard to their biological effects and how they can best be utilized in formulating economical animal diets. The following study had the objectives of supplying biological, as well as chemical data, on some common or potential

¹ Based on personal knowledge of the writer while working in the Ministry of Agriculture and Natural Resources, South Eastern State, Nigeria.

² A. R. Robblee, Professor of Poultry Nutrition, University of Alberta - Personal communication.

Nigerian food ingredients and comparing them with similar North American foodstuffs. The laboratory rat served as the experimental animal in these studies.

REVIEW OF LITERATURE

Introduction

Feeding experiments are now widely used in nutritional studies as a practical way of assessing different diets or the role of specific ingredients. The basic principle is not new, nor is the practice of extrapolating nutritional data from one species to the other. Thus, in diets consisting of single plants, Babcock, cited by Maynard and Loosli (1969), discovered that such diets were nutritionally inadequate to sustain the life of cows; for within three months, he lost one out of two cows on the experiment. To animal husbandmen in Babcock's days, this was too high a price to pay for research as it would be to most farmers in Nigeria today. Consequently his technique was abandoned for some time lest more cows be lost. However, the idea was revived later by Babcock's successors, Hart, McCollum, Steenbock and Humphrey (1911). These investigators later substituted rats for cattle as experimental animals. Since then, there have been numerous studies in which rats as experimental animals have contributed substantially to a better understanding of the nutritional needs of man and his farm animals. Moreover, the experiences of the intervening years have led to refinement of techniques and the evolution of many other empirical methods of food evaluation. These methods of evaluation can now be used singly or in combination depending, for example, on the object of evaluation, the sensitivity of the method, the time factor, the facilities available and the relative cost and convenience of each method.

In the Nigerian situation where protein is the most difficult and the most expensive nutrient to produce, one of the pressing needs in food evaluation is to assess the potentialities of local foodstuffs as protein supplements. Ultimately, of course, if protein is to be efficiently utilized, consideration must also be given to discovering how best to simultaneously supply other nutrients. A further consideration in the choice of evaluation techniques is the current shift of emphasis from "proteins" to "amino acids" as determinants of nutritive quality. Various methods used for protein or amino acid evaluation have been described in the literature. As far as possible therefore, this thesis will not duplicate these descriptions, except where it is considered appropriate to bring out subtle differences or similarities. In most cases, it will try to pinpoint the main advantages and disadvantages of each method as these influence the choice or the combination of choices available to a research worker.

Feeding Trials

The growth experiments of Osborne and Mendel (1919) were some of the early attempts to demonstrate the individuality of plant seeds in their protein contents and the variation of the proteins themselves in their amino acid spectra. Because the growth of animals represents in part an increase in lean mass, the method is valid to a limited extent. It would be more valid, were it not that growth per se is a measure not only of the increase in lean mass, but also of fat, ash and moisture. The inclusion of carcass data in such studies makes the results less misleading. Whole body counters are now being studied (Frahm et al, 1971). When and if they become practical research tools, they will

increase the precision of feeding trials by permitting the assessment on live animals of the effects of diets on carcass lean.

Nitrogen Balance Studies

This method was introduced as a supplement to feeding trials. Recently, nutritional balance techniques and their limitations have been extensively reviewed (Blaxter, 1967; Passmore et al, 1967). Nitrogen (N) balance studies can quickly give preliminary guidance on protein quality, but because of their usual short duration, they can be misleading when protein sources of widely differing characters are being compared over a longer span. Furthermore, because the animals usually waste varying amounts of feed depending on the physical characteristics of the feed and the degree of nutrient balance, N intake is usually overestimated. The opposite is true of N excretions, due to partial collection of feces and urine. These errors are additive and inflate apparent N retention. According to Pirie (1969), it is unusual to find experiments in which "retention" is not overestimated by 5 to 10%. He cites the case of infants in which N retention of 1g/day is often reported. A daily N retention of 1g would amount to a body weight increase of 15kg/yr. In his view, this is manifest nonsense when it is recognized that an infant contains 2 to 3% N on body weight basis. He therefore warns that N balance data should be treated skeptically and that apparent retention of 10% of N intake should be viewed as equivalent to zero balance. His equation, of course, is a priori and must in the writer's view be treated with some caution in relation to animal studies because the nature of the diet, the skill of the investigator, the design of the feed and water containers, differential adjustment to stress in

cages, variation in water intake, the storage conditions of the urine prior to analysis and other factors which vary from laboratory to laboratory affect both sides of the equation.

Apparent Biological Value (ABV)

$$ABV = \frac{N \text{ intake} - (\text{fecal N} + \text{urinary N}) \times 100}{N \text{ intake} - \text{fecal N}} \quad \text{is a measure of}$$

the percentage of the absorbed N that is retained. The measurements are identical to those involved in determining N balance and therefore subject to the same errors and criticisms. A basic assumption in nutrition is that for mature animals, $N \text{ intake} - \text{fecal N} - \text{urinary N} = 0$ or almost zero. The implication of this assumption which has recently been weakly challenged (Oomen, 1970) is that ABV is more meaningful when applied to growing animals, those producing milk or eggs or those developing fetuses.

True Biological Value (TBV)

This method credited jointly to Thomas (1909) and Mitchell (1924, 1936) was considered a refinement in precision over the N balance and ABV. It involves running, in addition to a balance study, a second trial with the animals fed a N-free diet in order to assess metabolic fecal and endogenous urinary excretions. These values, unlike the case of ABV, are excluded from the losses occurring from N intake. It does not account for cutaneous losses and these can be considerable in certain nutrient deficiencies such as essential fatty acid or zinc deficiencies precipitating dermatitis. Nor does it account for gaseous losses in monogastric animals which though normally considered slight are nevertheless there (Bowland et al, 1970). Consequently,

$$TBV = \frac{N_I - (F_N - F_{Nm}) - (UN - UN_e) \times 100}{N_I - (F_N - F_{Nm})} \quad \text{where } N_I = \text{N intake; } F_N =$$

fecal N, F_{Nm} = metabolic fecal N; UN = urinary N, UN_e = endogenous urinary N still falls short of perfection.

In effect, TBV measures the efficiency with which the absorbed N is utilized for maintenance and growth. A problem with this method is that some animals may refuse the N-free diet or fail to eat enough to meet their energy needs. Consequently, endogenous N may be underestimated. Similar problems apply to the determination of metabolic fecal N. To obviate the difficulty of using a N-free diet, a small amount of protein (4.5% egg protein, considered 100% digestible and metabolizable) is sometimes included in the N-free diet. Other investigators do not use a N-free diet. They calculate UN_e from body size using the equation: $UN_e \text{ (mg)} = 146 (W_{kg})^{0.75}$, where W_{kg} = the weight of the animal in kg developed by Brody et al (1934). Likewise, F_{Nm} is obtained by the extrapolation method of Titus (1927).

As pointed out by Pirie (1969), food protein is most efficiently utilized when the energy needs are fully met by fats and carbohydrates, and an amino acid shortage is the only factor restricting protein synthesis. In that case, the amino acids are avidly picked up at the sites of synthesis as the blood circulates them through the body. Because marginal deficiencies of amino acids can be compensated for by increased dietary protein level, the two observations when viewed together create complications in the interpretation of TBV's. As aptly stated by Crampton and Harris (1969), dietary protein level will modify the calculated TBV independently of the amino acid balance,

because deamination appears to proceed somewhat according to the law of mass action. The question therefore arises: at what level (percentage composition in diet) should the test protein be fed in order to obtain a realistic TBV; and in the light of the above, how would data obtained at one protein level fit into the practice of feeding different protein levels to different categories of animals? In attempt to answer this question, Maynard and Loosli (1969) suggest that the level of protein fed must be high enough to promote marked growth or production to correlate with the degree of positive balance. At the same time, it must not be in excess of the amount needed to cause maximum growth or else the excess will be catabolized and excreted, thus giving less than intrinsic biological value. When one relates this to the fact that new strains of animals are continually being developed by geneticists, the suggestion of Maynard and Loosli may be of limited value. Clearly, the TBV for individual feeds will change according to the level of incorporation in the diet and according to associative effects of dietary constituents. Although the practice of standardizing the level of test proteins to 10% of intake yields TBV's which allow objective and precise comparisons of protein sources between laboratories, it is not as good as testing the protein sources at the level that they would be applied in practice. Besides, the inherent UN_e and FN_m problems referred to above have made ABV more popular in recent years. Other shortcomings applicable to both ABV and TBV are that they are laborious to determine and knowledge of the BV of a protein source does not enable one to predict what BV is necessary to improve the quality of the particular protein, unless prior information is available regarding its amino acid pattern and availability.

Net Protein Value (NPV)

NPV was proposed by Mitchell and Carman (1924) and used by Mitchell (1944) to evaluate food products. It is an extension of the BV concept intended to portray the attributes of a protein source not only in digestibility, but also in metabolism and utilization. $NPV = CP \times \text{Digestibility Coefficient (expressed as decimal)} \times BV$ (expressed as decimal) where CP = crude protein. Mitchell (1944) claims that NPV is so accurate that with only 10 animals, it can detect differences as low as 2 or 3% in the digestibility and biological value of proteins; although one observes that in their earlier work (Mitchell and Carman, 1924) they obtained a NPV of 12.5%, 14.6% and 7.6% for egg, lean pork and whole wheat respectively. This ranks egg proteins second to lean pork, and in view of the usual superiority accorded to egg proteins, one wonders whether NPV can sometimes lead to erroneous ranking of protein supplements. It is, of course, true that like other factorially derived variables, the precision of NPV depends on how accurately the multipliers (CP, digestibility coefficient and BV) are determined.

Net Protein Utilization (NPU)

This is the proportion of N intake that is retained, i.e. the product of biological value and digestibility.

$$NPU = \frac{B - B_k}{I}$$

Where B = Body N measured at the end of the test period on animals fed the test diet.

B_k = Body N at zero N intake measured at the end of the test period on animals fed a non-protein diet.

I = N intake.

It is termed "calculated" when obtained from the "determined" values of the biological value and from the digestibility according to the formula:

$$\text{NPU "calculated"} = \text{BV} \times \text{D (where D = digestibility)}$$

This distinction (Anonymous, 1970) avoids the apparent confusion created in the literature by Bender and Miller who use NPV and NPU interchangeably (Bender and Miller, 1953; Miller and Bender, 1955).

In their 1953 work just cited, these investigators showed mathematically that any attempt to determine NPV (NPU "calculated") by multiplying the conventional Thomas-Mitchell BV by the digestibility coefficient is aiming at the impossible, because it implies doing carcass N analysis on the same rat fed non-protein and test diets. They therefore proposed that carcass N on the non-protein diet or on a diet containing 4.5% egg protein (whichever is used) be estimated by the use of control animals which should be littermates of equal weight to the test animals. The test proteins are incorporated at the 10% level and the diets are fed for only 10 days, at the end of which the rats are killed and the body N determined by kjeldahl digestion of the whole carcass. The analyses for each treatment group are pooled and the data substituted in the equation: $\text{NPV (i.e. NPU "calculated")} = \frac{B_f - B_k + I_k}{I_f}$, where B_f and B_k are the total body N of the animals on the test and non-protein diets respectively, and I_f and I_k are the intake of N in the two groups. Compared with the classical Thomas-Mitchell method of estimating BV, this procedure reduces not only the number of measurements but also the experimental period. Moulton (1923) had shown that body constituents are constant proportions of the body when measured on a fat-free basis. Utilizing this information (Bender and Miller, 1953) in

another experiment were able to prove that the ratio N/H_2O is a constant; and therefore they could derive the N content of the body of experimental animals from the moisture content. This finding further simplifies the procedure and makes it possible to determine NPU on live animals since body water can be measured, for example, by isotopic dilution, urea or antipyrine. A close look at the NPU values derived from the latter procedure shows that although they correlate with those obtained from actual measurements of N, they are about 1.5% higher. This makes the correlation with the actual nutritive value of the test proteins less accurate, although the sacrifice in accuracy is probably compensated for by the savings in time, labour and costs.

Liver Nitrogen

Mokady, Viola and Zimmerman (1969) by a method analogous to the conventional NPU method studied N retention by the livers of rats fed different protein supplements. They obtained 0.85 correlation with NPU values determined on the carcasses of rats from which livers had been removed after slaughter. It would be interesting to verify whether similar agreement could be obtained if the N contents of the livers were estimated from the N/H_2O ratio mentioned earlier. These investigators cited Allison (1964) to support the view that the susceptibility of different organs to changes in the quality of nutritional proteins is in the order: blood > liver > muscle > kidney > brain. A further implication for research, therefore, is the need to verify whether similar correlations can be obtained by determining N in blood samples of experimental animals after a meal.

Other investigators have also used liver N to assay proteins.

Henry et al (1953), following the suggestion of Kosterlitz (1944) that the sensitivity of liver N to dietary proteins could provide a measure of protein quality, outlined a method for measuring the increase in liver N(mg)/100 g initial body weight of rats on the test diet. They admitted, however, that their method though time-saving was less sensitive than the balance sheet method. Rippon (1959) using the method of Henry et al (1953) noted that it did not appear to offer a reliable measure of protein quality.

Protein Replacement Value (RV)

RV was introduced by Murlin (1938) to avoid the limitations of the Thomas-Mitchell BV:

$$RV = 100 - \frac{100 (NB_1 - NB_2)}{Ni}$$

Where NB_1 = N balance for standard protein in mg/basal kg

NB_2 = N balance for test proteins, same conditions.

Ni = N intake of the test having the larger N consumption. If N intakes are nearly equal, Ni = the average N intake of the two tests.

Two N balances are conducted with N intakes essentially equal. Egg or milk protein often serves as the basal protein. $\frac{100 (NB_1 - NB_2)}{Ni}$ represents the extent to which the one protein has biologically failed to match the other. The complement of this percentage is RV and indicates the extent to which a given protein can replace the other in terms of N balance.

Some of the weaknesses of RV are that it is time-consuming, and being influenced by digestibility, absorbability and metabolic efficiency,

two proteins differing in these attributes can have equal RV. RV values are therefore relatively difficult to interpret and offer no information on how to improve a protein having an undesirably low value.

Protein Efficiency Ratio (PER)

Introduced by Osborne and Mendel (1919),

$$\text{PER} = \frac{\text{g body wt. gain}}{\text{g protein consumed}}$$

is the most widely used criterion in protein evaluation. Its value depends on dietary protein level. The protein giving the higher body weight gain per unit of protein intake is ranked superior to one giving a lower gain. Consequently, it overlooks the fact that all body weight gain is not lean and that a substantial amount of the "gain" could be fat or water or bone. Oser (1970) has enumerated other assumptions and disadvantages of PER. Some of these disadvantages are given under Protein Nitrogen Efficiency (page 15).

Net Protein Ratio (NPR)

This method involves the use of a control group fed a protein-free diet.

$$\text{NPR} = \frac{\text{g gain} - \text{g increment of controls}}{\text{g protein eaten}}$$

The use of a protein-free diet has inherent difficulties discussed earlier. Like PER, NPR only measures net growth with no distinction between the components of gain.

Protein Retention Efficiency (PRE)

A modification of NPR,

$$\text{PRE} = \frac{100 (\text{NPR})}{6.24}$$

Although the modification facilitates interlaboratory comparison of

values, there appear to be no additional advantages over the NPR method of protein evaluation.

Total Protein Evaluation (TPE)

TPE is a further modification of PER formally proposed by Woodham and McDonald (1968). This method uses 18.5% total CP level (12% CP from the test protein, and 6.5% from cereals) instead of the conventional 10%. It has the advantage that as far as chicks are concerned, the level approaches that of a practical chick starter ration. Moreover, the proportions of cereal and supplementary protein are also similar to those used in practice. Another advantage is that the procedure makes it possible to evaluate certain protein supplements which though inadequate as a sole source of protein may make a useful contribution as complements to the basal cereals.

Protein Nitrogen Efficiency (PNE)

$$PNE = \frac{\text{g gain}}{\text{g N intake}}$$

By definition, PNE is similar to PER, except that protein intake is expressed as N. The advantage in expressing gain relative to N intake is that the kjeldahl procedure normally used for the determination of protein really determines total N. The use of N is therefore theoretically more accurate than protein values derived from $N \times 6.25$, since the factor (6.25) could vary depending on the protein source. Some of the disadvantages of PNE also shared, of course, by PER are:

- (a) The partial dependence of the results on other dietary factors and on age, strain of animals and pretest nutritional history.
- (b) Inability to provide information concerning the slope of the response curve - a common weakness in single point bioassays.

(c) Difficulty of assessing low protein products containing less than the conventional 10% protein level, though this may be overcome by feeding reference casein at a correspondingly low level.

(d) Inability to distinguish between gain in moisture, muscle, adipose and skeletal tissues.

(e) Laboriousness, expensiveness and time consumption.

Nitrogen Incorporation Efficiency (NIE)

Baja et al (1971) introduced this method.

$$\text{NIE} = \frac{\text{Nitrogen retained in carcass}}{\text{Nitrogen intake}} \times 100$$

Whereas in their comparison of NIE with PER, they observed close correlation between the two, they noted that net growth alone did not rank the protein sources studied in the same order as PER or NIE. Obviously, this method (NIE) is an attempt to distinguish protein from the other components of gain. This fact explains the lack of agreement with protein evaluation based on gross growth.

Efficiency of Food Utilization (EFU)

$$\text{EFU} = \frac{\text{g gain}}{100 \text{ g food eaten}}$$

Food Efficiency (FE)

$$\text{FE} = \frac{\text{g food eaten}}{\text{g net gain}} \quad \text{or its reciprocal.}$$

Unless all other dietary essentials are adequate for optimum performance, both EFU and FE could be measuring variables other than relative protein qualities.

Gross Protein Value (GPV)

As proposed by Heiman et al (1939),

$$\text{GPV} = \frac{\text{Amount of casein that will give the same extra growth as test protein}}{\text{Amount of test protein eaten}} \times 100$$

This procedure was modified by Robertson et al (1940), who expressed GPV as

$$\frac{\text{Extra gain on test diet}}{\text{g protein consumed by birds on test diet}} \times$$

$$\frac{\text{g protein consumed by birds on casein diet}}{\text{Extra gain on casein diet}} \times 100$$

The test diet really consisted of 8% CP from a basal diet + 3% CP from the test protein. The casein diet consisted of 8% CP from the basal diet + 3% CP from casein. On the grounds that the above versions of GPV did not take into consideration the protein intake from the unsupplemented basal diet, Anwar (1960) suggested a now widely accepted formula for calculating GPV.

$$\text{GPV} = \frac{A - a}{A_0 - a} \times 100$$

Where A = g gain/g supplementary protein

A_0 = g gain/g supplementary casein consumed

a = g gain/g protein from unsupplemented basal diet.

Values obtained by Anwar's method are about 28% higher than those from the previous two. Although other modifications have since been proposed, the basic approach to GPV determination remains unchanged.

Some of the criticisms of GPV are that it is laborious and as pointed out by Heiman et al (1939), the value obtained will not indicate the basic cause of the failure of a particular supplement to produce a satisfactory response in growing chicks. Failure could be due to low palatability, poor digestibility, laxative effects, amino acid imbalance

or other causes. However, the method is flexible, a fact which is both advantageous in that the actual determination could be adapted to a given situation, and also disadvantageous in that the results so obtained cannot be generalized.

True Protein

This is a now obsolete term formerly used by some European scientists to try to distinguish from the total N content of a compound, the amount of N actually present in proteins from the chemical standpoint.

Protein Quality Index

A term introduced by Almquist et al (1935) in attempt to relate the analytical characteristics of various proteins to their nutritive values.

$$\text{Protein Quality Index} = A - (B + 0.6C) + 0.4D$$

Where A = % of total N precipitated by copper (inclusive of B and C)

B = % of total N not digestible

C = % of total N as hot-water-soluble protein

D = % of total N precipitated by phosphotungstic acid.

Evans and St. John (1945) found good agreement between protein quality index and the relative protein nutritive value of vegetable protein concentrates studied, with the exception of overcooked soybean meals. In the light of current knowledge on the effect of heat on amino acids, their findings appear to suggest that protein quality index could provide some measure of amino acid availability, although in this regard it cannot compete with other alternative methods available today.

Crude Protein (CP = N X 6.25)

Although in practice the factor 6.25 is normally used, in fact it may vary. Crude protein does not indicate how much of the N the

animal can use, and two proteins having identical CP values could differ markedly in their nutritive value.

Apparent Digestible Crude Protein (DP)

$$DP = N_I - F_N$$

True Digestible Protein (TDP)

$$TDP = N_I - (F_N - F_{N_m})$$

CP, DP and TDP in that order represent an increasing refinement in protein evaluation criterion. Being derived from kjeldahl analysis, their weakness lies in their failure to distinguish between protein N and non-protein N. For example, they include in proteins the N occurring in amides, nitrates, nitrites and urea. This weakness has contributed to the current emphasis placed on amino acid composition, balance and availability.

Amino Acids As Criteria Of Protein Quality

It is now widely recognized that amino acid composition, pattern and availability are the main determinants of protein quality. Various amino acid assay techniques have therefore been developed. Among these, automated analysis has contributed much to our knowledge of amino acid composition; though as pointed out by Davidson and Hepburn (1970), the technique has its own problems. For example, errors may arise from the colorimeter, variations of energy supplied to the lamp, environmental temperature and the technique of loading samples on the autoanalyser. In addition, automation has not resolved the problem of determining tryptophan occurring in protein-bound form in biological materials (Evans et al, 1970). Knowledge of total amino acids is of limited value; for even in cases where the amino acid spectrum appears favour-

able, this may not correlate directly with protein quality, because of differences in availability. In view of this limitation, chemical scores have come into use (Block and Mitchell, 1946; Oser, 1951). Chemical scores provide numerical values for protein quality by considering the relative amounts of the amino acids present in the test protein compared with those present in whole egg protein. Available lysine value (Carpenter et al, 1955, 1957, 1959, 1960) with suggested modifications by various investigators (Baliga et al, 1959; Rao et al, 1963) is another approach to amino acid availability. A modification of Carpenter's method which deserves special mention in that it has earned its own name the "Silcock Method" is that of Roach, Sanderson and Williamson (1967). Their modification involves the determination of "total" and "residual" lysine from which available lysine can be obtained by difference. The method has been found useful for vegetable proteins and mixed diets (Matheson, 1968; Ostrowski et al, 1970). These various methods and their modifications are contributing somewhat to more precise evaluation of amino acids. However, as pointed out by Thomas (1970), none of them is completely adequate to provide the information needed to interpret the processes of digestion, absorption and conservation of protein in the animal, especially when one realizes that the really meaningful criterion in metabolic studies is turnover rather than static concentration. In his view isotopic labelling and measurements must comprise an essential part of the amino acid assay technique. In practice, however, isotopic labelling technique has so far not been extensively used in amino acid studies, in spite of its accuracy and precision.

Microbiological Methods

These constitute another approach toward evaluating protein in a dynamic rather than a static state. It has long been known that certain micro-organisms, for example, the bacteria Streptococcus zymogenes and the protozoan Tetrahymen pyriformis have amino acid requirements similar to those of man or domestic animals. This has prompted many investigators (Fernell and Rosen, 1956; Ford, 1960, 1965, 1971; Horn et al, 1952, 1954, 1961) to use micro-organisms in amino acid studies.

Like the other procedures so far discussed, the microbiological method has limitations. A major one is that it does not employ directly the animals to which results will be related; and as Ford (1965) remarked "it is not possible to reproduce in vitro the digestive milieu of the gut in which the food protein is assailed with a full armamentarium of enzymes." Secondly, when S. zymogenes is used as the experimental micro-organism, the protein is predigested enzymatically before assay. The results thus obtained differ according to the enzyme system employed in the predigestion (Ford, 1965; Szmelcman and Guggenheim, 1967).

Blood Plasma Amino Acid Levels

As blood is the major transport vehicle in the body, the blood plasma concentrations of amino acids after a meal could reflect the dietary protein quality. This is truer of the portal than the systemic blood. This fact has been used to evaluate proteins directly in the species or category of animals upon which the findings are to be ultimately applied. However, as observed by Myres (1970), attempts to use plasma amino acid patterns to predict limiting amino acids and the nutritive value of a protein supplement for growth and maintenance have

yielded discrepancies or only approximate results; and direct correlation of plasma amino acid levels with protein quality has not been achieved. Factors which could contribute to discordance in the literature include, for example, those influencing the rate of stomach emptying. Porter and Rolls (1971) have explained some of the factors involved.

Other Blood and Urine Components

Conditions which limit urea excretion or increase its formation raise blood urea levels in those animals which normally excrete excess N as urea. In normal physiological conditions, blood urea level correlates well with protein intake. Poor quality protein gives a higher blood urea level compared with an equal intake of high quality protein. Preston et al (1965) have suggested that the measurement of blood urea N level would provide a means of evaluating the adequacy of protein nutrition in ruminants.

Choice of Foodstuffs for Evaluation

Ideally all foodstuffs, not only those in use but also potential ones should be evaluated. However, within the terms of the present study, only a limited number of foodstuffs could be evaluated. Priorities therefore had to be established on the choice of materials for evaluation. Two main criteria were used. First, Nigeria's current production of the foodstuffs and the capacity for increased production. Second, the historical role of each crop or crop product, viewed on a world-wide basis. The Nigerian foodstuffs used in the present study are corn, guinea corn (a sorghum) and peanut meal. Appendix Table i shows the production data for Nigeria taken from the Food and Agriculture

Organization Production Yearbook, (Anonymous, 1970). If adequate allowance is made for the depressing effect of the civil war (1967-70) on agricultural production, the figures indicate the production trends of the major food energy and protein supplements in Nigeria. Production figures for yams and rice are not included, although these contribute considerably to energy consumption in Nigeria. However, they are hardly, if ever, used for livestock feeding. They are mainly for human consumption. A comparison of the average yields of the various crops with the corresponding yields in North America (Appendix Table i) suggests that there are large potentialities for increased production of these crops, not only by increasing acreages under cultivation but also by increasing yields through the sound use of fertilizers, adoption of higher yielding crop varieties, and general improvements in crop husbandry and storage.

Historical Roles of Cereals and Legumes in Human Welfare

Man's evolutionary status, while it owes a lot to favourable adaptive changes in his genetic make-up, has also depended much on nutrition. In this regard, his history has been closely associated with the cultivation of plants. The number of species on which he has depended, and which are still his sole means of dietary intake, directly or indirectly, is small and of these cereals and pulses (legumes) have made the greatest impact (Bell, 1969). In some countries, wheat and rice are the major representatives of cereals, and soybean the main representative of the pulses. In Nigeria, cereals are represented by sorghums, millets, rice and corn (maize), and the pulses by peanuts (groundnuts), although some soybeans and other beans are also grown. It is appropriate at this stage to consider from an empirical point of view the comparative

nutritive roles of these crops or their by-products. The consideration is limited to foodstuffs used in this study.

Corn (Zea mays)

Corn is native to tropical America, where it has been cultivated for over 6,000 years. There are conflicting views as to when it was introduced into Nigeria (Oyenuga, 1967). Some say that it was introduced around A.D. 1502 (10 years after the discovery of America). Others believe that it was introduced earlier than A.D. 1502 from Ancient Egypt by Yoruba immigrants. Corn is sun-loving, and requires an annual rainfall of 30 inches or above. It is therefore suited to the tropical conditions prevailing in Nigeria, especially in the southern half of the country. It can resist drought but not as much as sorghums. In Nigeria, this accounts for the gradual spread of the crop to the drier northern regions.

Although corn is primarily a source of energy, it contains about 9% crude protein and therefore contributes substantially to the protein of diets. Corn, in common with most cereals, is deficient in lysine and tryptophan. Corn also supplies minerals and vitamins. Corn is fairly rich in thiamine, but low in vitamin D, riboflavin and niacin. In those parts of the world where corn is the principal diet, this low niacin and tryptophan content has been responsible for a high incidence of pellagra.

Guinea Corn (Sorghum guineense)

Guinea corn is a tropical crop originating in West Africa (Oyenuga, 1967) and the largest cultivated single cereal crop in Nigeria. It grows well in those parts of the country where the annual rainfall varies from 25 to 50 inches. It will also withstand annual rainfall as

low as 15 inches. Being drought-resistant, it is grown mostly in those parts of Northern Nigeria which are too dry to support maize. Like the dietary values of corn just reviewed, guinea corn supplies protein, minerals and vitamins in addition to energy. It is, however, lower than corn in soluble carbohydrates, oils and mineral matter, though higher (15%) in crude protein (Oyenuga, 1967, 1968). As with most other cereals, the protein of guinea corn is low in methionine, cystine, lysine and tryptophan. It is very low in calcium, sodium, chlorine, iron, copper and cobalt but somewhat high in phosphorus. Although the young leaves of guinea corn are known to contain the glycoside, dhurrin, the hydrocyanic component of which is poisonous, this toxic principle is absent from the guinea corn grain.

Peanuts or Groundnuts (*Arachis hypogaea*)

Peanuts are a fairly adaptable crop native to tropical South America. The crop was introduced to West Africa by the Portuguese. Peanuts are the third most important crop in Nigeria. Peanut meal (groundnut cake) is the residual product after the extraction of the oil from peanuts. The meal is high in energy and protein, but the protein is low in lysine, methionine and threonine (Oyenuga, 1967). Peanut meal from well hulled nuts is palatable to stock and its nutritive quality is said to approach closely that of soybean meal when used for dairy cattle, beef cattle, sheep, horses and swine. It is only of slightly lower value when used for poultry (Ewing, 1947). Peanut meal is somewhat laxative, especially if high in fat. If fed in excess, it may result in the formation of soft fat.

A problem which has become associated with peanut meal during the past decade is aflatoxin, produced by *Aspergillus flavus*. Aflatoxin

is poisonous to livestock. Ducks appear to be particularly susceptible and are therefore used as test animals to indicate the presence or absence of aflatoxin in foodstuffs. Twenty mg of aflatoxin can kill a day-old duckling in 24 hours (Oyenuga, 1967). The attack of peanuts by aflatoxins can be minimized by careful harvesting, drying and storage. So far, there is no evidence to show that aflatoxin is toxic to the human. However, this potential problem cannot be ruled out as mycotoxins are potential hazards to man. Vorster (1969) has proposed a method for the analysis of cereals and groundnuts for three mycotoxins (aflatoxin, ochratoxin and sterigmatocystin). The method is based on a subjective evaluation of thin-layer chromatograms of a single sample extract. Vorster considers the method satisfactory for rapid determination of the approximate level of mycotoxin toxicity. If it eventually proves useful for the rapid screening of various batches of peanut meal for mycotoxin contamination, it will help to remove the present fear associated with the feeding of peanut meal to livestock.

Soybeans (Glycine max)

Soybeans are probably one of the oldest crops. They were cultivated in China as early as 2838 B.C. (Oyenuga, 1968). In Nigeria, this crop is relatively new. Its cultivation is expanding, but only within the past 10 years has an effort been made to process the seeds locally. Consequently, soybean meal is not yet a major protein supplement in Nigeria. In China and Japan on the other hand, soybeans have served for centuries as a major source of plant protein. More recently it has become the major supplemental protein source for livestock feeding in the United States and in Canada.

Soybean meal is high in protein and relatively rich in lysine and tryptophan. If improperly processed, trypsin inhibitor which is active in raw soybeans can constitute a problem. However, commercially available soybean meal is considered superior to all other plant protein supplements which are used extensively.

The comparative merits and demerits of the foodstuffs thus presented are merely indicative of what a nutritionist might expect of each kind of foodstuff. In practice, the nutrients in the soils on which plants grow vary from place to place and from year to year (Buckmand and Brady, 1969). Indeed, soils are in a dynamic state. The climate also varies from year to year and from place to place. The climate is in a continuous flux. The plants themselves may change somewhat from generation to generation as they try to adapt to a changing environmental pressure. Therefore for current information on the nutritive value of foodstuffs emanating from a given source, the foodstuffs must be continually evaluated. This stresses the need for rapid, precise, evaluation techniques and the importance of accurate sampling of foodstuffs.

Summary

From Babcock's era to the present much information has appeared in the literature on techniques of food evaluation. The various methods proposed are intended to serve as short-cuts to determining the value of an ingredient in a diet formulated for man or his animals. "The proof of the pudding is in the eating and what is wanted is reliable assessment of the diets as eaten by animals or man in health or disease, in plenty or want;" (Henry and Kon, 1958). Historically, human depletion

experiments are considered unethical and unpopular. Hopefully, discrete extrapolation of data obtained from experiments conducted with laboratory animals can therefore provide answers to the malnutrition problems now confronting Nigeria and her livestock, as it has done, for example, in North America.

EXPERIMENTAL

Objectives

An experiment was conducted during 1971 with two primary objectives. The first objective was to evaluate peanut meal (groundnut cake) which is a common Nigerian protein supplement in combination with two Nigerian energy sources (yellow corn and guinea corn) at three levels of dietary protein¹ (20, 16 and 12% crude protein) in diets formulated on an isocaloric basis (3,600 kcal/kg), when these diets were fed to weanling rats. The second objective was to compare the value of the Nigerian foodstuffs with similar North American foodstuffs.

Treatments

The experiment had seven major dietary treatments. The calculated gross composition of the diets fed on these treatments is shown in Appendix Table ii, the protein and amino acid composition in Appendix Tables iii(a) and iii(b). Within each main dietary treatment, there were three sub-treatments consisting of protein levels of 20, 16 and 12%. The method of formulating these diets to maintain a constant essential amino acid ratio and a similar digestible energy (DE) to protein ratio between sub-treatments was as described: 4,800 g of the 20% protein diet was mixed in each case and 2,000 g retained for the rats on that treatment; 1,600 g was mixed with 360 g starch and 40 g vermiculite² to obtain the 16% protein diet; 1,200 g was mixed with 720 g starch and 80 g vermiculite to obtain the 12% protein diet. The levels of supplements were those shown in the footnote to Table 1B.

¹ Protein = Nitrogen X 6.25

² Vermiculite is a trade name for exfoliated mica.

The Nigerian corn [C(Nig)], guinea corn [GC(Nig)] and peanut meal [PNM(Nig)] were obtained by air express from Nigeria. The Canadian corn [C(Can)] and soybean meal [SBM(Can)] were purchased locally.

Four rats (2 males and 2 females) of Sprague-Dawley breeding (Department of Animal Science, The University of Alberta strain) were stratified into weight groups, such that the total weight of rats on the various treatments agreed within 4 g of each other. The rats were housed individually in 18 X 24 X 18 cm³ anti-coprohagy cages in a temperature and humidity-controlled room (22.2°C, 45% R.H.). Food and water were supplied ad libitum. Cages were cleaned and body weights and food intake recorded weekly.

Carcass Analyses

At the end of a 4-week experimental period, the rats were killed with chloroform. The digestive tract, exposed by mid-ventral incision, was emptied of ingesta. Weights of individual rats without the ingesta were recorded immediately as empty body weight. The carcasses were then dried in an oven at 60°C for 72 hours. After equilibration with the atmosphere, the weights were again recorded as air-dry empty body weights. Individual carcasses were then enclosed in labelled plastic bags and frozen in dry ice (-42.8°C) for a minimum of 1 hour before grinding. The rats were ground for 1-3 minutes (Christy and Norris "8-inch laboratory mill"¹), using a 0.317 cm mesh screen. To ensure that the grinder was cool, dry ice was ground before each rat was ground. Each rat was broken into small pieces and ground along with some dry ice. This procedure froze the fat and prevented it separating in the grinder

¹ Christy and Norris Ltd., Chelmsford, England.

and clogging the screen. Each ground rat was quantitatively collected in its corresponding plastic bag and stored at room temperature until all the dry ice (CO_2) had sublimated, leaving behind the ground carcass. The bagged carcasses were stored in a cool room (4.4°C) until it was convenient to do chemical analyses on them. The ground product was homogeneous as revealed by the close agreement between duplicate Kjeldahl nitrogen and crude fat analyses.

Carcass and food analyses for total nitrogen, crude fat, dry matter and ash were done in duplicate. Foods were also analyzed for crude fiber (AOAC, 1965). For the nitrogen determination, a commercial "Kel-Pak"¹ was used to supply the catalyst and the ammonia was collected in boric acid. Food energies were determined with a Parr Oxygen Bomb Calorimeter.² Amino acid contents of food ingredients (Appendix Tables iv to vi) were obtained either with a "Technicon"³ or with "Type-5AH"⁴ amino acid analyzer. Values obtained with the two instruments agreed closely.

At the start of the experiment, 8 representative rats (4 males, 4 females) were killed to obtain data to estimate the chemical composition of the rats at the beginning of the experiment.

¹ Matheson Scientific, East Rutherford, New Jersey. This supplied a mixed catalyst containing K_2SO_4 and CuSO_4 .

² Parr Instrument Company, Moline, Illinois. Temperature changes registered by a Brown Electronik Recorder manufactured by Minneapolis-Honeywell Regulator Company, Philadelphia, Pennsylvania.

³ Technicon Auto Analyzer, Technicon Instruments Corporation, Chauncey, New York, U.S.A.

⁴ Amino Acid Analyzer, Type JLC-5AH manufactured by Japan Electron Optics Co. Ltd., Tokyo, Japan. A faster analyzer which arrived in the course of the experiment.

Digestion and Retention Studies

In the fourth week of the experiment, 3-day digestion and retention experiments were conducted on all 42 males. These experiments were conducted using methods as described by Hussar and Bowland (1959) except that a 3-day rather than 7-day collection period was used. Two lots of 21 rats, each representing all dietary treatments, were used in these studies. Dates of the metabolism experiments were June 15 to 18 for the first lot and June 18 to 21 for the remaining lot.

Statistical Procedures

Analyses of variance were computed to determine significant differences. As indicated earlier, the sources of variation were ration ($N = 7$, see Tables 1A and 1B), levels of protein (12, 16 and 20%), sex (male and female), replicates ($n = 2$) and for traits measured weekly, age (1, 2, 3 and 4 weeks). Additional analyses were made by deleting diet numbers 7a, b and c, C(Can) - PNM(Nig) - ML. This deletion allowed the remaining six rations to be analyzed according to source of energy [C(Can), C(Nig), GC(Nig)] and source of protein [SBM(Can) and PNM(Nig)].

The sources of variation of the traits measured in the digestibility and retention studies were the same as listed above, except that there was no source due to sex, as only male rats were studied. In all analyses, sources of variation except rats were considered fixed. The mean squares are shown in Appendix Tables vii to ix. Where appropriate, multiple comparisons of means were made using Duncan's multiple range test (Steel and Torrie, 1960).

Table 1A. Dietary ingredients and composition (%)

Major DE source*	Canadian Corn			Nigerian Corn			Nigerian Guinea Corn			Canadian Corn		
Major protein source*	Canadian SBM			Canadian SBM			Canadian SBM			Nigerian Peanut Meal		
Estimated crude protein	20%	16%	12%	20%	16%	12%	20%	16%	12%	20%	16%	12%
Calculated DE (kcal/kg)	3629.5	3622.0	3618.0	3629.5	3622.0	3618.0	3523.5	3538.0	3554.0	3585.0	3587.0	3591.0
Diet number	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c
Ingredients												
Corn (Canadian)	53.0	42.4	31.8	53.0	42.4	31.8				55.8	44.64	33.48
Corn (Nigerian)							53.0	42.4	31.8			
Guinea corn (Nigerian)												
Peanut meal (Nigerian)												
SBM (Canadian)	33.5	26.8	20.1	33.5	26.8	20.1	35.5	26.8	20.1	30.0	24.0	18.0
Stabilized tallow	6.0	4.8	3.6	6.0	4.8	3.6	6.0	4.8	3.6	6.0	4.8	3.60
Starch	2.2	19.76	37.32	2.2	19.76	37.32	2.2	19.76	37.32	2.2	19.76	37.32
Vermiculite	1.8	3.44	5.08	1.8	3.44	5.08	1.8	3.44	5.08	2.2	3.76	5.32
Ground limestone	1.3	1.04	0.78	1.3	1.04	0.78	1.3	1.04	0.78	1.4	1.12	0.84
Calcium Phosphate	1.1	0.88	0.66	1.1	0.88	0.66	1.1	0.88	0.66	1.3	1.04	0.78
Trace mineral premix ¹	0.5	0.40	0.30	0.5	0.40	0.30	0.5	0.40	0.30	0.5	0.40	0.30
Vit. B-complex premix ²	0.5	0.40	0.30	0.5	0.40	0.30	0.5	0.40	0.30	0.5	0.40	0.30
Vit. B ₁₂ ³	0.1	0.08	0.06	0.1	0.08	0.06	0.1	0.08	0.06	0.1	0.08	0.06
Vit. A ⁴	+	+	+	+	+	+	+	+	+	+	+	+
Vit. D ⁵	+	+	+	+	+	+	+	+	+	+	+	+
Vit. E ⁶	+	+	+	+	+	+	+	+	+	+	+	+
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* Hereafter diets are designated according to energy and protein sources and are abbreviated as follows: Canadian corn - Canadian SBM = C(Can)-SBM(Can); Nigerian corn - Canadian SBM = C(Nig)-SBM(Can); Nigerian Guinea corn - Canadian SBM = GC(Nig)-SBM(Can); Canadian corn - Nigerian peanut meal = C(Can)-PNM(Nig); Nigerian corn - Nigerian peanut meal = C(Nig)-PNM(Nig); Nigerian Guinea corn - Nigerian peanut meal = GC(Nig)-PNM(Nig); Canadian corn - DL-methionine + L-lysine = C(Can)-PNM(Nig)-ML.

1-6 For level of supplementation, see Table 1B.

Table 1B. Dietary ingredients and composition (%) (continued)

Major DE source	Nigerian Corn		Nigerian Guinea Corn		Canadian Corn	
Major protein source	Nigerian Peanut Meal		Nigerian Peanut Meal		Nigerian Peanut Meal	
Estimated crude protein	20%	16%	20%	16%	20%	16%
Calculated DE (kcal/kg)	3585.0	3587.0	3473.0	3498.0	3585.0	3587.0
Diet number	5a	5b	6a	6b	7a	7c
	5c		6c			
Ingredients						
Corn (Canadian)					55.8	44.64
Corn (Nigerian)	55.8	44.64				33.48
Guinea corn (Nigerian)			55.8	44.64		
Peanut meal (Nigerian)	30.0	24.0	30.0	24.0	30.0	24.0
SBM (Canadian)						18.00
Stabilized tallow	6.0	4.8	6.0	4.8	6.0	4.8
Starch	2.2	19.76	2.2	19.76	2.2	19.76
Vermiculite	2.2	3.76	2.2	3.76	1.6	3.28
Ground limestone	1.4	1.12	1.4	1.12	1.4	1.12
Calcium phosphate	1.3	1.04	1.3	1.04	1.3	1.04
Trace mineral premix ¹	0.5	0.40	0.5	0.40	0.5	0.40
Vit. B-complex premix ²	0.5	0.40	0.5	0.40	0.5	0.40
Vit. B12 ³	0.1	0.08	0.1	0.08	0.1	0.08
Vit. A4	+	+	+	+	+	+
Vit. D5	+	+	+	+	+	+
Vit. E6	+	+	+	+	+	+
L-lysine (feed grade) ⁷						
DL-methionine (feed grade) ⁸						
	100.0	100.0	100.0	100.0	100.0	100.0

For the 20% protein diets

- 1 Supplies the following per kg of mixed food: 1.66 mg cobalt carbonate, 12.39 mg copper sulphate, 0.66 mg ethylene diamine dihydroiodide, 118.8 mg ferrous carbonate, 24.13 mg manganese oxide, 1.50 mg zinc oxide, and 33.42 mg limestone.
- 2 Supplies the following per kg of mixed food: 2.22 mg riboflavin, 4.44 mg calcium pantothenate, 10.1 mg niacin, 11.13 mg choline chloride, and 0.33 mg folic acid.
- 3 Supplies 0.002 mg vitamin B12 per kg of mixed food.
- 4 To supply 66,150 I.U. vitamin A per kg of mixed food.
- 5 To supply 866.58 I.U. vitamin D2 per kg of mixed food.
- 6 Provides 322.47 I.U. vitamin E (c - tocopherol) per kg of mixed food.
- 7 L-lysine mono HCl (98%), Pfizer Co. Ltd. Montreal, Quebec.
- 8 DL-methionine (99%), Degussa, West Germany.

Definition of Terms(a) Urinary Energy

Insufficient urine from the 3-day trials necessitated the calculation of urinary energy from the following equation:

$$U_E = U_V \times U_N \times 0.46 \times 15.16 \text{ kcal.}$$

Where U_E = Urinary energy of rats (kcal)

U_V = Volume of rat urine (mls)

U_N = % N in rat urine

0.46 = % N in urea

15.16 = kcal/g of urea

(b) Gross Energy in Carcass Fat

$$GE_F = C_F \times W \times 9.40 \text{ kcal}$$

Where GE_F = Gross energy in carcass fat

C_F = % fat in carcass

W = Wt. of rat (dry matter basis)

9.40 = kcal/g fat

(c) Gross Energy in Carcass Proteins

$$GE_P = C_P \times W \times 5.65 \text{ kcal}$$

Where GE_P = Gross energy in carcass protein

C_P = % protein in carcass

W = Wt. of rat (dry matter basis)

5.65 = kcal/g protein

(d) Gross Energy in Rat Carcass

$$GE_R = GE_F + GE_P$$

Where GE_R = Gross energy in rat carcass and GE_F and GE_P are as defined above.

(e) N-corrected Metabolizable Energy

$$ME_N = GE_i - FE - GPD - UE \pm (NB \times 6.29 \text{ kcal; Metta and Mitchell, 1954})$$

(f) Carcass N as Percentage of Calculated N Retention

$$\frac{\text{Carcass N}}{\text{Calculated N Retention}} \% = \frac{N_C (DM_E - DM_I)}{N_R \times N_F \times F_I} \times 100$$

Where N_C = % N in individual rat carcass (dry matter basis)

DM_E = Dry matter content of individual rats at end of experiment

DM_I = Average dry matter content of rats slaughtered initially

N_R = Average % N retention of male replicates on the same diet

N_F = % N in each diet. The same value for all rats (2 males and 2 females) on identical diets.

F_I = As fed food intake g

RESULTS AND DISCUSSION

The results are considered under three main headings:

- (a) Rate of gain and food efficiency
- (b) Carcass analyses
- (c) Energy and N digestion and retention.

As far as possible, the traits covered under each heading are discussed in the same sequence in which they are tabulated.

Table 2. Symbols used in levels of significance between and among means

Symbols used	Meaning
*	Means are significantly different at $p \leq 0.05$.
**	Means are significantly different at $p \leq 0.01$.
a, b, c, d, e	Means in the same column with the same superscript or no superscript are not significantly different at $p \leq 0.01$.
A, B C, D, E	Means in the same column with the same superscript or no superscript are not significantly different at $p \leq 0.05$.

Liveweight Gain

On the basis of cumulative liveweight gain, PNM was inferior ($P \leq 0.01$) to SBM (Table 3). Average gain for the 4-week period for rats fed SBM was 48.4 g and for rats fed PNM was 34.8 g. Bielorai (1969) in in vitro and in vivo studies with chicks compared SBM with PNM, using both toasted and untoasted meal in each case. He found that raw SBM was not significantly different from raw PNM but that toasted SBM was significantly ($P \leq 0.01$) better than toasted PNM when evaluated on the basis of chick growth. He attributed the equality of the raw meals to the combined effects of their differences in the contents of tryptic inhibitor, and differences in amino acid balance. Raw SBM has a higher anti-tryptic activity, but a superior amino acid balance; raw PNM on the other hand has a medium anti-tryptic activity and a relatively poor amino acid balance. When the anti-trypsin effects of the two meals are reduced or removed by toasting, the superior amino acid balance of SBM manifests itself in significantly higher chick growth. Our present study with rats confirms this superiority of heated SBM over heated PNM.

Supplementation of the C(Can)-PNM(Nig) with methionine and lysine did not improve ($P \leq 0.01$) the PNM diets. Supplementation of the PNM diets was calculated to raise the level of methionine and lysine to that of the control C(Can)-SBM(Can) diets. Anantharaman and Carpenter (1969, 1971) have shown that in the processing of PNM the type of heat (wet heat versus dry heat), the processing temperature and the duration of heating affect the nutritive value of the PNM. Dry heating tends to lower, wet heating tends to raise, though not significantly, the protein quality of PNM when NPU is used as a criterion of quality. Severe heating lowers

Table 3. Influence of protein and energy sources on liveweight gain, food consumption and efficiency of food conversion for the 4-week experimental period

Protein and energy source	Cumulative gain (g)	Food Consumption (g)	Efficiency of food conversion (g)/gain (g)
C(Can)-SBM(Can)	43.3 ^{bc}	262.5 ^{de}	6.08 ^b
C(Nig)-SBM(Can)	48.5 ^{cd}	256.3 ^{bc}	5.30 ^c
GC(Nig)-SBM(Can)	53.4 ^d	274.0 ^f	5.12 ^c
C(Can)-PNM(Nig)	36.8 ^{ab}	268.6 ^{ef}	7.32 ^a
C(Nig)-PNM(Nig)	35.6 ^{ab}	258.6 ^{cd}	7.28 ^a
GC(Nig)-PNM(Nig)	31.8 ^a	242.9 ^a	7.61 ^a
C(Can)-PNM(Nig)-ML	36.0 ^{ab}	250.7 ^b	7.00 ^a

the protein quality of PNM, although PNM is relatively resistant to heat damage when compared with materials rich in reducing sugars. Overheating reduces the value of available lysine more than it does methionine. In the 1971 study, Anantharaman and Carpenter (1971) observed that with chicks, dietary supplementation with methionine (+ cystine), lysine and threonine gave a large response in growth. Without the threonine, a non-significant response was obtained. The further addition of tryptophan gave another significant response. This pattern of limiting amino acids contradicted the findings of other investigators; for example, Grau (1946) who found that for chickens, methionine was the first limiting amino acid in peanut meal; and Fisher (1964, 1965) who found the first limiting amino acid for the same species to be lysine. With rats, Anantharaman and Carpenter (1971) also reported a good response when amino acid supplements of methionine,

lysine and threonine were fed. However, these investigators remarked that "the interpretation of results from supplementing 'groundnut protein' diet for rats with amino acids has often been a problem." A possible explanation, they said, lies in the fact that the amino acid requirement of the rat changes in the period after weaning. Some of the discrepancies in the literature may therefore be associated with differences in the length of the experimental period and possibly also to varietal differences in the groundnut. One might add to the above, the differences in processing temperatures. It is to be expected that this could vary from batch to batch even in the same processing plant. In the case of PNM from Nigeria, this is understandable when it is appreciated that the emphasis hitherto had been on the peanut oil rather than PNM. In the present study, the above factors may explain the negative response to the supplementation of the C(Can)-PNM(Nig) diets with methionine and lysine alone.

There were interactions between protein sources and energy sources (Figure 1). SBM(Can) gave the best gain, 53.4 g, when GC(Nig) supplied the energy. C(Nig)-SBM(Can), average 48.5 g, seemed to be a better combination than C(Can)-SBM(Can), average 43.3 g. With PNM, the pattern of interaction was reversed. GC(Nig)-PNM(Nig), C(Nig)-PNM(Nig) and C(Can)-PNM(Nig) averaged 31.8 g, 35.6 g and 36.8 g respectively. Although this evaluation was focussed on proteins (amino acids), each plant protein supplement brings to a diet not only amino acids but also its full complement of all nutrients, known and unknown. Therefore, in complex practical diets such as were used in this study, significant differences could originate from any of the multiple associative effects

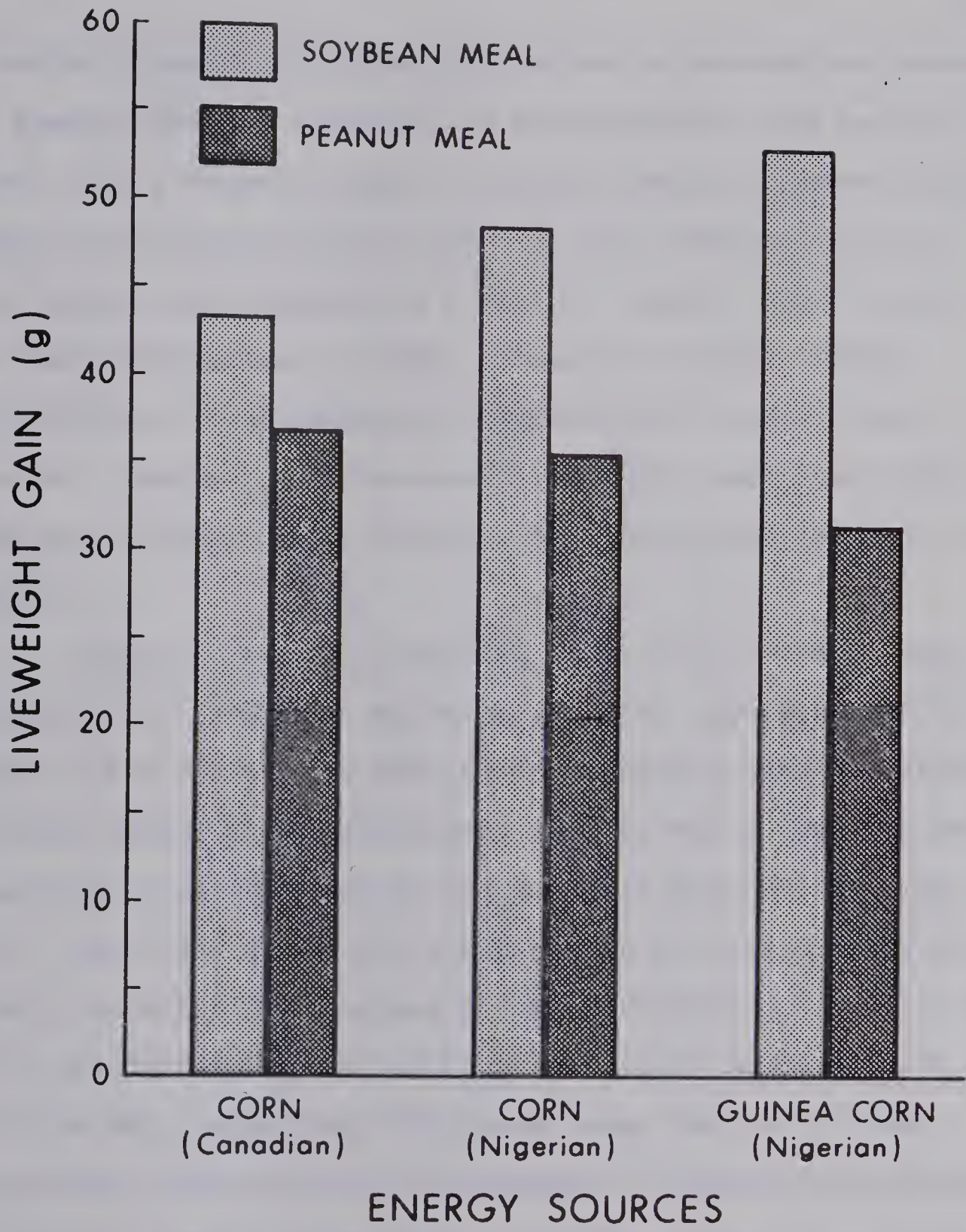


Figure 1. Interaction of protein and energy sources on cumulative liveweight gain.

of nutrients other than the ones upon which major attention was focussed. For example, different complements of polysaccharides could exert different binding effects on lysine. Different mineral complements could offset the calculated mineral-vitamin balance. These possibilities could obscure the interpretation of results. Appendix Table i shows that North American corn is higher yielding than C(Nig). However, "yield/hectare" is not necessarily synonymous with "nutrient yield/hectare." Therefore it is conceivable that C(Nig) combined with SBM(Can) gave a better overall nutrient balance than C(Can) combined with SBM(Can).

Protein level had no significant effect on the 4-week average liveweight gain (Table 4). Bowland et al (1958), using diets varying widely in N to energy ratio associated an increasing ratio of dietary N to dietary energy with a significantly improved rate of gain. In the present study, protein level had no significant effect on liveweight gain. Rats on 12% protein diet gained as much as those on 16 and 20% protein diets, but at the expense of higher ($P \leq 0.05$) food intake. The 12, 16 and 20% protein diets had calorie to protein ratios of 178.6, 223.6 and 298.7 respectively. This study shows that over a 4-week experimental period weanling Sprague-Dawley rats receiving diets varying in calorie to protein ratios from 180 to 300 were physiologically able to adjust food intake to achieve equal liveweight gains.

Males gained faster than females, except in the fourth week. This appears to agree with the observation (Drill, 1961) that male and female rats grow at approximately equal rates until about the 30th day of age, when sexual maturity starts. Males then begin to grow faster,

Table 4. Influence of protein level and sex on liveweight gain, food consumption and efficiency of food conversion for the 4-week experimental period

Protein level (%)	Cumulative gain (g)	Food Consumption (g)	Efficiency of food conversion (g)/gain (g)
20	40.1	256.8 ^A	6.41 ^{ab}
16	42.8	258.4 ^A	6.04 ^b
12	39.3	262.1 ^B	6.74 ^a
Sex			
Male	43.1	266.0	6.22
Female	38.3**	252.2**	6.56*

thus ending up with a larger mature body weight than females. Increased androgen secretion occurs in both sexes as they approach maturity. This may explain the burst of growth seen in both sexes at this time (Carlson, 1969). In our experiment, this increase in gain was so large in the females in the 7th week of life (4th week on experiment) that they gained faster than males (Figure 2).

Food Consumption and Food Conversion

On a cumulative basis, food consumption showed an inconsistent trend, with the SBM diets tending to give the highest food intake (Table 3). Average food conversion [gain (g)/food (g)] for SBM diets was 5.5 and for PNM diets was 7.4. This may account partially for the higher growth rate exhibited by the rats on the SBM diets compared with those fed the PNM diets.

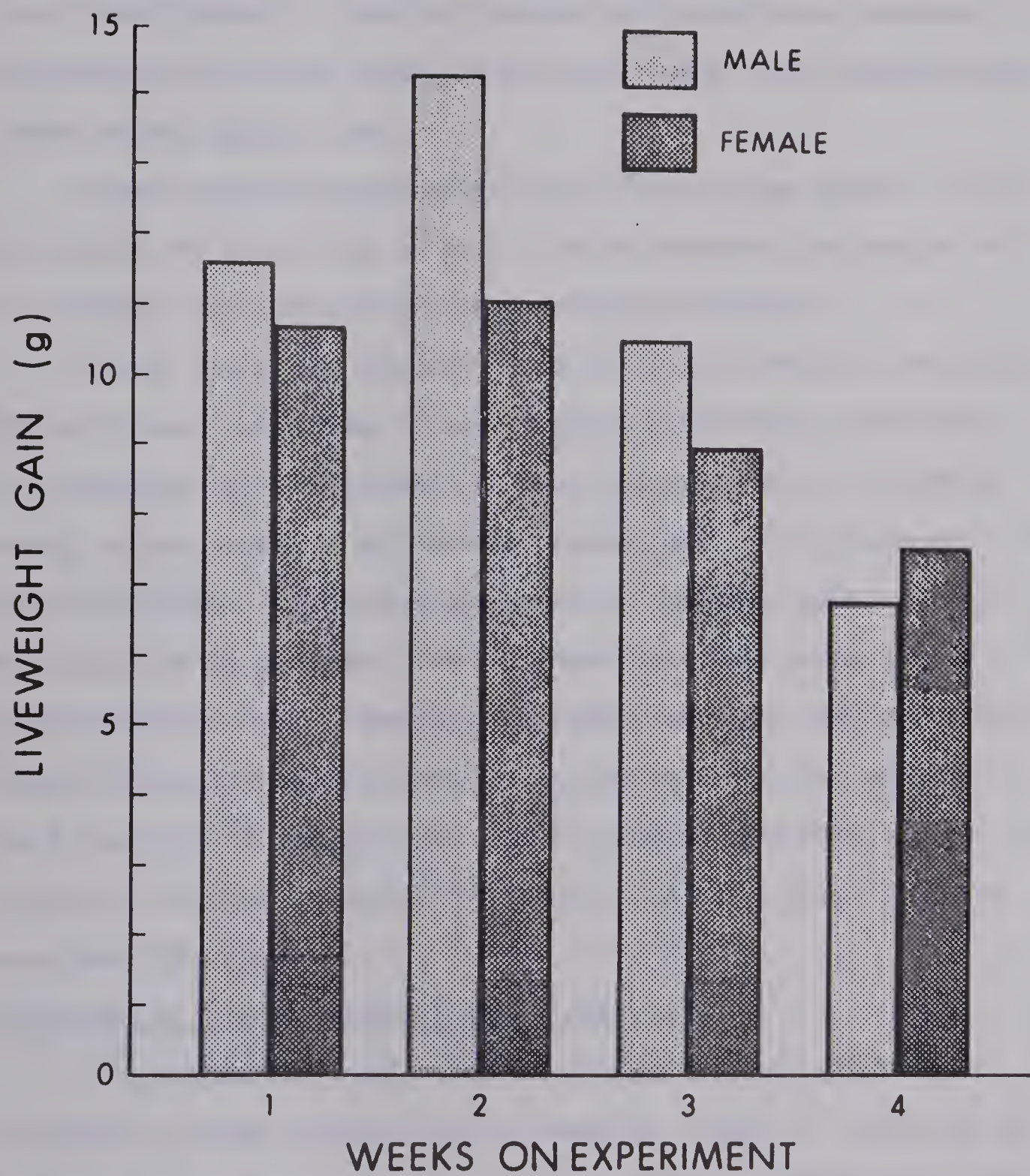


Figure 2. Effect of sex on average weekly liveweight gain.

Dietary protein level had no significant effect ($P \leq 0.01$) on food intake (Table 4). This is in accord with expectation, because in rats energy, not protein level, is the major factor that determines food intake (Sibbald et al, 1956).

Males consumed significantly more ($P \leq 0.01$) than females. This may explain the faster rate of gain of males compared with females and is probably a reflection of an inborn genetic difference.

Energy source had a marked effect on food intake with the GC(Nig)-SBM(Can) giving the highest intake. Energy digestibility data showed that this diet was comparatively high in available energy. Therefore energy did not appear to be directly responsible for the relatively high food intake. N retention percentage on the other hand, although not significantly different from the other diets, was lowest on the GC(Nig)-SBM(Can) diet. Sibbald et al (1956) had shown that digestible energy consumption could account for as much as 69% of the variation in the N retention of weanling rats. In the present experiment much of the explanation for the variation in N retention might be sought in amino acid insufficiencies.

Efficiency of Food Conversion [food (g)/gain (g)]

In general, SBM-supplemented diets were superior ($P \leq 0.01$) to PNM diets in 4-week cumulative food conversion (Table 3). SBM-supplemented diets gave an average food conversion of 5.5 g food/g gain against 7.4 g food/g gain for the PNM diets.

Energy source significantly affected ($P \leq 0.01$) the cumulative food conversion in the SBM, but not in the PNM diets. The best result for cumulative food conversion of 5.1 g food per g gain was obtained

with the GC(Nig)-SBM(Can) diet. This was not significantly different from 5.3 food per g gain recorded for the C(Nig)-SBM(Can) diet; but both were different ($P \leq 0.01$) from 6.1 g food per g gain obtained with the C(Can)-SBM(Can) diet.

Amino acid supplementation of the C(Can)-PNM(Nig) diet improved food conversion slightly but not significantly.

No significant difference was observed in cumulative food conversion between 20 and 16% dietary protein level. However, the 12% protein level was inferior ($P \leq 0.01$) to the 16 but not to the 20% protein level. This difference decreased with age (Figure 3), suggesting that 12% dietary protein level might be adequate for the maintenance of adult Sprague-Dawley rats. The recommended protein requirement for the growth of rats is 20% crude protein and for maintenance 7% crude protein (National Research Council, 1962). It is evident that the change from 20 to 7% crude protein is gradual rather than sudden, but it is not clear at what age the requirement would decrease below 12% protein.

One obvious reason for the poorer food efficiency observed at the 12% dietary protein level is that in order to meet their amino acid requirements, rats on the 12% protein diets consumed significantly more food ($P \leq 0.05$) than those on the 16 or 20% protein diets. Secondly, much of the liveweight gain made by rats fed the 12% protein diets was fat when compared with the tissue composition of the rats fed the other diets (Figure 4). Fat has a higher energy value per unit of weight than the other components of gain (protein, ash and moisture) and this contributes to low food efficiency.

Males were superior to females ($P \leq 0.05$) in 4-week cumulative food conversion (Table 4).

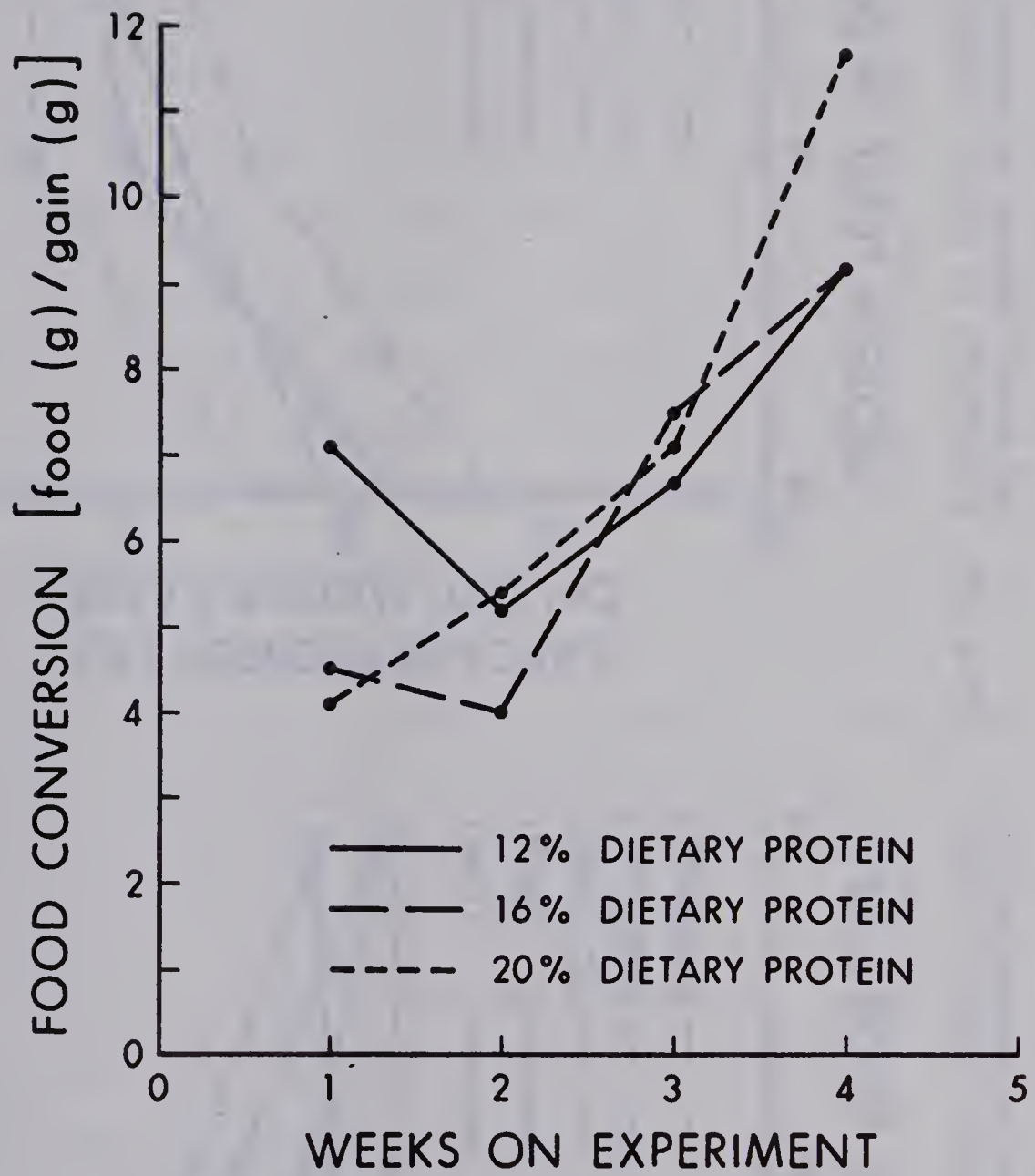


Figure 3. Weekly food conversion [food (g)/gain (g)] of rats fed three levels of dietary protein.

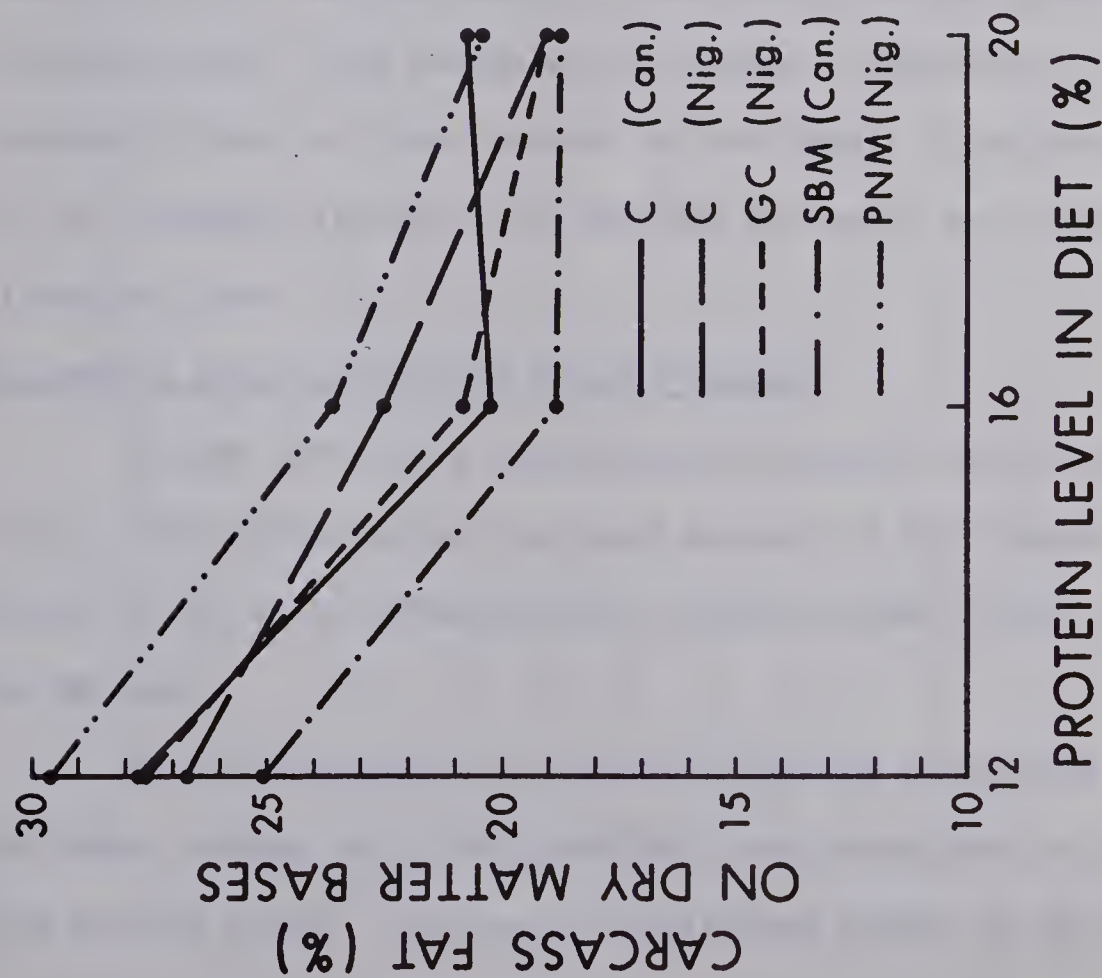


Figure 4(a) Interaction of dietary protein levels and energy sources on carcass fat (%).

(b) Interaction of dietary protein levels and protein sources on carcass fat (%).

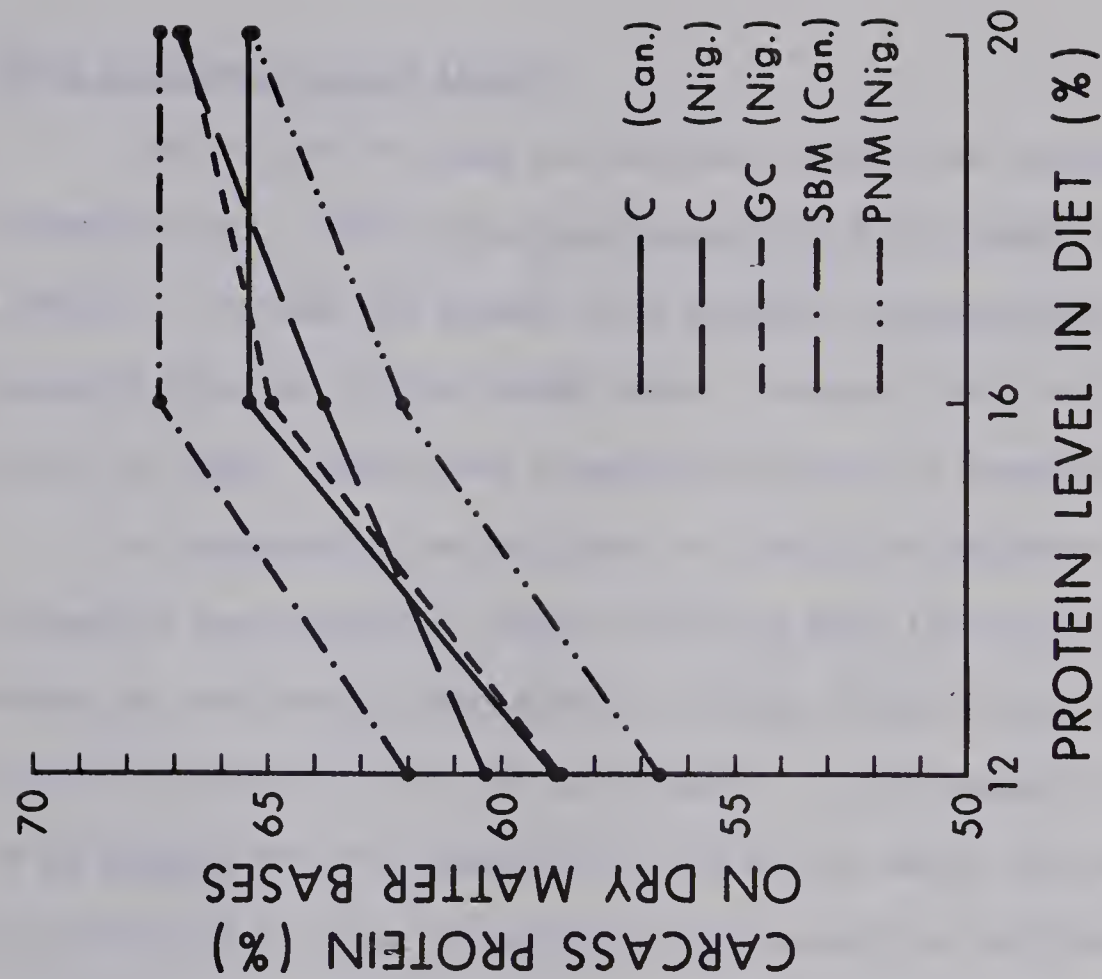


Figure 5(a) Interaction of dietary protein levels and energy sources on carcass protein (%).

(b) Interaction of dietary protein levels and protein sources on carcass protein (%).

Empty Body Weight Gain (EBWG)

The pattern for EBWG was similar to that for cumulative weekly liveweight gain. SBM diets gave higher ($P \leq 0.05$) EBWG's than PNM diets (Table 5). GC and SBM seemed to be mutually supplementary, while the opposite obtained in the GC-PNM diets. Protein level had no significant effect on EBWG. Males were superior ($P \leq 0.01$) to females (Table 6).

An explanation may be given for the close agreement of EBWG with liveweight measurements. Since the diets were isocaloric and rats eat mainly to meet energy requirements, energy intake should approximate to a constant proportion of the liveweight. On the assumption that under an ad libitum feeding regimen the rats eat at about the same time, then with the kind of diets involved in this study, any differences due to variation in digestive tract emptying are likely to be negligible. Consequently, the EBWG represents a relatively constant proportion of the liveweight gain. For comparative purposes, therefore, in this study the liveweight gain is a good measure of the EBWG. This view is supported by the constancy ($P \leq 0.01$) of the EBWG expressed as a percentage of the liveweight gain.

Dry Matter (DM) Gain and DM Food Conversion

The SBM diets gave significantly higher DM gain than the PNM diets, except where C(Can) provided energy for PNM (Table 5). Supplementation of the C(Can)-PNM(Nig) with methionine and lysine did not improve the DM gain.

DM food conversion was better ($P \leq 0.01$) on the SBM than on the PNM diets, except for C(Can)-SBM(Can) diet, which was not different from the PNM diets. Sex had no significant effect on DM food conversion.

Table 5. Influence of protein and energy sources on rate of gain and efficiency of food conversion on an empty body weight and dry matter body weight basis

Protein and energy source	Empty Body Weight		Dry Matter Body Weight	
	Cumulative gain (g)	Efficiency of food conversion (g)	Cumulative gain (g)	Efficiency of food conversion (g)
C(Can)-SBM(Can)	38.5 ^B	6.86 ^b	12.4 ^{ab}	21.05 ^a
C(Nig)-SBM(Can)	42.2 ^{BC}	6.12 ^c	14.3 ^{bc}	17.95 ^b
GC(Nig)-SBM(Can)	46.6 ^C	5.89 ^c	16.6 ^c	16.50 ^b
C(Can)-PNM(Nig)	32.4 ^A	8.32 ^a	12.3 ^{ab}	21.74 ^a
C(Nig)-PNM(Nig)	30.7 ^A	8.42 ^a	11.2 ^a	23.26 ^a
GC(Nig)-PNM(Nig)	28.0 ^A	8.82 ^a	10.3 ^a	23.20 ^a
C(Can)-PNM(Nig)-ML	31.0 ^A	8.14 ^a	11.1 ^a	22.78 ^a

Table 6. Influence of protein levels and sex on rate of gain and efficiency of food conversion on an empty body weight and dry matter body weight basis

Protein level (%)	Empty Body Weight		Dry Matter Body Weight	
	Cumulative gain (g)	Efficiency of food conversion (g)	Cumulative gain (g)	Efficiency of food conversion (g)
20	34.2	7.58 ^a	11.67	22.08 ^a
16	37.3	6.94 ^b	13.21	19.57 ^b
12	35.3	7.52 ^a	12.94	20.37 ^b
Sex				
Males	38.5	7.02	12.74	21.05
Females	32.8**	7.69**	12.47	20.16

(Table 6). This was also the case when food conversion was measured on a liveweight basis (Table 4).

There was no significant difference in DM food conversion between 16 and the 12% dietary protein; but both were higher ($P \leq 0.01$) than food conversion for rats fed 20% protein. On a liveweight basis, however, food efficiency at the 20, and 12% dietary protein levels, were not significantly ($P \leq 0.01$) different. Liveweight food conversion for the 16% dietary protein was higher than that of the 12% dietary protein but not that of the 20% dietary protein. Both the DM and liveweight food conversion indicate that the cumulative food efficiency up to 7 weeks of age is not better on the 20% protein diet than on the 12% diet. From the protein point of view only, it would appear that feeding a 12% protein diet would permit an increase of approximately 50% in the number of rats kept. In practice, this would be a point in favour of the 12% protein diet.

On a liveweight basis, efficiency of food conversion on the 16% dietary protein was superior ($P \leq 0.01$) to the 12% dietary protein; but on a DM basis, there was no significant difference between the two. It would appear, therefore, that the traditional practice of measuring efficiency on the basis of liveweight gain has limited value when the primary objective is to supply animal proteins, not water, to a protein mal-nourished population.

Carcass Analyses

Diet significantly affected the percentage carcass lean and fat ($P \leq 0.01$) but not the percentage ash, or the EBW expressed as a percentage of liveweight (Table 7).

Table 7. Influence of protein and energy source on carcass analyses

Protein and energy source	Carcass Analyses (%)				$\frac{\text{EBW}^1}{\text{LW}}$
	Protein	Fat	Ash	Dry Matter	
C(Can)-SBM(Can)	65.7 ^{cd}	20.4 ^a	11.9	30.0 ^a	91.5
C(Nig)-SBM(Can)	66.0 ^d	20.9 ^a	11.8	30.3 ^{ab}	90.5
GC(Nig)-SBM(Can)	64.9 ^{bcd}	21.2 ^{ab}	11.7	31.1 ^{abc}	90.4
C(Can)-PNM(Nig)	60.8 ^a	25.4 ^c	11.7	32.2 ^c	91.5
C(Nig)-PNM(Nig)	61.3 ^a	24.8 ^{bc}	11.7	31.2 ^{abc}	90.8
GC(Nig)-PNM(Nig)	62.0 ^{ab}	23.7 ^{abc}	11.9	31.7 ^{bc}	91.7
C(Can)-PNM(Nig)-ML	62.3 ^{abc}	23.8 ^{abc}	11.7	30.9 ^{abc}	90.7

¹ EBW = Empty Body Weight; LW = Liveweight

In general, carcass protein percentage was higher with the SBM diet than with the PNM diet (Figure 5). This effect appeared to be most pronounced when SBM and C(Nig) were used together, and least pronounced when SBM and GC were together. However, there were no significant differences between the various SBM diets in carcass protein percentage. With PNM, on the other hand, carcass protein percentage was highest when PNM was used in conjunction with GC. In both cases, complementary amino acids in the protein supplement and cereals probably account for the favourable interaction; but as suggested earlier, attention should not be focussed on protein only, since other nutrients may contribute to favourable supplementary effects. Supplementation with

methionine and lysine insignificantly increased carcass protein percentage.

Similar trends as above were observed when carcass protein percentage was calculated on a fat-free basis. Carcass protein percentage of rats fed SBM-supplemented diets averaged 82.8 against 82.0 for rats on PNM-supplemented diets. Rats fed C(Nig)-SBM(Can) diets had an average carcass protein percentage of 83.4 against 82.4 for rats fed GC(Nig)-SBM(Can). GC(Nig)-PNM(Nig) gave an average carcass percentage lean of 81.3 against 81.5 for C-PNM(Nig). C(Nig) and C(Can) when used with PNM(Nig) gave identical (81.5) carcass lean percentage. Statistical tests were not conducted on carcass protein percentage on a fat-free basis, but any observed differences were negligible compared with values determined on the whole carcass. In North America and other parts of the world where overnutrition is a problem, these differences could, in animal production, have important practical significance on consumer acceptance. However, on a world-wide basis and particularly in areas where calorie and protein malnutrition co-exist, the viewpoint should be "protein good, calories good", Carpenter (1970). This was the basis for determining protein content of whole rather than defatted carcasses.

Opposite effects were observed in carcass fat percentage compared with carcass lean. On the whole, SBM diets gave a lower fat percentage ($P \leq 0.01$) than PNM diets. Carcass fat percentage was minimal when SBM was used in conjunction with C(Can), and maximal when it was used together with GC. Since fat synthesis is less expensive in energy than protein synthesis (Bayley, 1971), the above observation suggests that on

the whole, the metabolizable energy (ME) of the GC(Nig)-SBM(Can) diets was lower than, though not significantly different from, the ME in the C-SBM(Can) diets. This observation is in agreement with the comparative ME values for maize and sorghum presented by Carpenter (1970).

Both protein level and sex significantly influenced carcass protein percentage (Table 8). The 12% dietary protein level gave significantly lower carcass protein percentage ($P \leq 0.01$) than the 16 or 20% dietary protein levels which did not differ in this respect. Males excelled females ($P \leq 0.01$) in carcass protein percentage.

Table 8. Influence of protein level and sex on carcass analyses

Protein level (%)	Carcass Analyses (%)				$\frac{EBW^1}{LW}$
	Protein	Fat	Ash	Dry Matter	
20	66.1 ^b	19.8 ^a	12.2 ^b	30.2 ^a	90.1 ^a
16	64.6 ^b	21.4 ^a	11.9 ^b	31.0 ^a	90.8 ^{ab}
12	59.1 ^a	27.4 ^b	11.3 ^a	32.0 ^b	92.2 ^b
Sex					
Males	64.4	21.7	11.8	30.4	91.8
Females	62.2**	24.0**	11.7	31.7**	90.2**

¹ EBW = Empty Body Weight; LW = Liveweight

On a fat-free basis, the 12, 16 and 20% protein diets, in that order, gave average carcass protein percentages of 81.6, 82.1, and 82.5 respectively. Male rats averaged 82.2 against 81.8% for females. As in the case of the ingredient source effects, the differences were small compared with carcass protein determined on the whole carcass.

Dietary protein levels and sex also influenced ($P \leq 0.01$) carcass fat percentage. Sixteen and 20% dietary protein levels were not significantly different in their effects upon carcass fat percentage, but both resulted in less fat ($P \leq 0.01$) than the 12% protein diets. Males stored less fat and more lean than females.

Twenty percent dietary protein level was not better than the 16% in carcass ash percentage; however, both resulted in higher ($P \leq 0.01$) carcass ash percentage than the 12% protein diet. This probably implies that the ratio of bone to lean in rats fed the two kinds of diets (20 and 16% protein) are similar.

Sex had no significant effect on carcass ash percentage; but it affected ($P \leq 0.01$) DM percentage, with males giving a lower DM percentage. This agrees with the earlier observation that with the type of diets used in this study, much of the extra weight gain in males was moisture. Therefore, the implication is that the apparent superiority of males as portrayed by extra liveweight gain should not be taken at its face value.

Carcass N/N Retention (CN/NR) Percentage

Little agreement was observed between carcass N and N content of the carcass calculated from N retention (Table 9). The former averaged 40.3% of the latter. This probably reflects to some extent the inaccuracies of N balance studies.

Table 9. Influence of protein and energy sources and protein levels on N digestion and retention and comparison of carcass N with N retention based on retention studies

Protein and energy source	Metabolism Period				N retained N intake %	N ret. % D.N.	Daily N dig(mg)	Daily N ret.(mg)	Carcass N N retention %
	Wt. of Rat(g)	Av. Daily Food(g)	D.N.%						
C(Can)-SBM(Can)	93.0 ^{ab}	11.5 ^b	84.2 ^b	54.4	64.6	247 ^b	155 ^b	36.0 ^{ab}	
C(Nig)-SBM(Can)	94.9 ^{ab}	10.8 ^{ab}	82.8 ^{ab}	45.7	55.1	227 ^{ab}	123 ^{ab}	51.1 ^c	
GC(Nig)-SBM(Can)	103.3 ^b	10.9 ^{ab}	77.4 ^a	42.0	54.1	203 ^{ab}	110 ^a	60.2 ^d	
C(Can)-PNM(Nig)	81.0 ^a	10.5 ^{ab}	82.0 ^{ab}	43.4	53.3	225 ^{ab}	117 ^{ab}	40.3 ^b	
C(Nig)-PNM(Nig)	78.8 ^a	10.3 ^{ab}	84.1 ^b	53.0	62.9	225 ^{ab}	143 ^{ab}	30.5 ^a	
GC(Nig)-PNM(Nig)	78.6 ^a	9.3 ^a	81.5 ^{ab}	52.2	63.9	193 ^a	120 ^{ab}	32.4 ^a	
C(Can)-PNM(Nig)-ML	81.1 ^a	9.7 ^a	80.8 ^{ab}	54.2	67.3	208 ^{ab}	133 ^{ab}	31.3 ^a	
Protein level (%)									
20	87.9	10.5	82.2	43.5 ^a	52.7 ^a	269 ^c	144 ^b	34.8 ^a	
16	89.1	10.1	81.0	49.3 ^{ab}	60.3 ^{ab}	211 ^b	126 ^{ab}	42.6 ^b	
12	84.8	10.7	82.2	55.1 ^b	67.5 ^b	174 ^a	117 ^a	43.4 ^b	

Table 10. Influence of protein and energy sources and protein levels on DE, ME, and ME_N.

Protein and energy source	DE(%)	ME(%)	ME _N (%)	DE/DAY(kcal)	ME/DAY(kcal)
C(Can)-SBM(Can)	86.6	83.2	80.9	39.2	38.6
C(Nig)-SBM(Can)	86.3	82.9	83.3	38.7	37.9
GC(Nig)-SBM(Can)	85.4	85.3	81.3	37.2	36.2
C(Can)-PNM(Nig)	84.8	84.7	81.3	35.7	34.9
C(Nig)-PNM(Nig)	87.3	86.0	84.6	36.4	35.8
GC(Nig)-PNM(Nig)	86.8	85.5	84.3	33.3	32.8
C(Can)-PNM(Nig)-ML	86.6	85.3	84.1	33.9	33.4
Protein level (%)					
20	84.3 ^a	82.0 ^a	79.7 ^a	36.8	35.8
16	85.2 ^a	83.8 ^a	81.9 ^a	35.0	34.4
12	89.2 ^b	88.3 ^b	86.8 ^b	37.2	36.8

Protein level inversely influenced CN/NR ratio, with 12% and 16% dietary protein giving a higher value ($P \leq 0.01$) than the 20% protein diets. Although CN/NR percentage for the 12% dietary protein was slightly higher than that of the 16% dietary protein, it was not significantly different.

Sex had no significant effect on CN/NR percentage. In the calculation of CN/NR percentage, it was assumed that males and females are the same in N (protein) retention. It should be noted, however, from

the actual carcass analyses (Table 8) that this assumption appears to be incorrect.

Gross Energy

Gross energy from carcass fat and carcass protein respectively and the total energy in the carcass (Tables 11 and 12), were obtained by multiplying the fat and the protein contents by appropriate factors (pp. 35 and 36). They are therefore not discussed further, as they are, in fact, indirect measures of carcass fat and carcass protein and agree in general with the direct measures of these factors.

Empty Body Weight/Liveweight (EBW/LW) Percentage

Diet had no significant effect on EBW/LW percentage (Table 7); but the influence of sex on this variable was consistent with the sex effect on the liveweight gain. Males gained more ($P \leq 0.01$) than females (Table 4). Likewise, the EBW/LW percentage for males was higher ($P \leq 0.01$) than those of the females (Table 8). This agreement is consistent with the hypothesis that EBW is a relatively constant proportion of liveweight. Protein level was inversely related to EBW/LW percentage. Thus 20% dietary protein level gave an EBW/LW percentage which was less ($P \leq 0.01$) than that obtained with 12% dietary protein level. Sixteen percent dietary protein level gave an EBW/LW percentage which was intermediate between the two but not significantly different ($P \leq 0.05$) from that of the 20% protein diet. The constancy of EBW/LW percentage which exists between the various diets therefore appears to be the outcome of the combined function of sex and protein level.

Energy and N Digestibility and Retention

Although at the beginning of the experiment, the rats were uniformly distributed to all the treatments on the basis of liveweight, by

Table 11. Influence of protein and energy sources on gross energy (kcal) from carcass fat and carcass protein

Protein and energy source	Gross Energy (kcal) From		
	Carcass Fat	Carcass Protein	Total in Carcass
C(Can)-SBM(Can)	53.0	102.8 ^{abc}	155.8 ^{ab}
C(Nig)-SBM(Can)	58.6	110.1 ^{bc}	168.7 ^{ab}
GC(Nig)-SBM(Can)	64.1	116.4 ^c	180.6 ^b
C(Can)-PNM(Nig)	65.6	94.4 ^{ab}	160.0 ^{ab}
C(Nig)-PNM(Nig)	61.2	98.6 ^{abc}	152.2 ^a
GC(Nig)-PNM(Nig)	57.0	89.5 ^a	146.5 ^a
C(Can)-PNM(Nig)-ML	58.6	92.5 ^{ab}	151.1 ^a

Table 12. Influence of protein levels and sex on gross energy (kcal) from carcass fat and carcass protein

Protein level %	Gross Energy (kcal) From		
	Carcass Fat	Carcass Protein	Total in Carcass
20	49.9 ^a	103.7	150.4
16	57.1 ^a	103.8	160.9
12	72.2 ^b	94.3	166.5
Sex			
Males	56.7	101.7	158.4
Females	62.7	99.5	160.1

the time of the digestibility and retention studies, those fed PNM diets were significantly lighter ($P \leq 0.05$) than those fed SBM diets. In view of the above observation and the fact that rats are considered to be in a continued state of growth during their lifetime (Dunn et al, 1947), the results obtained in the digestibility and retention studies (Tables 9 and 10) may, in fact, reflect not only treatment effects but also differences in physiological age.

The average daily food intake was practically the same for all diets, except C(Can)-SBM(Can) which was significantly higher ($P \leq 0.01$) than GC(Nig)-PNM(Nig). Because the rats had by this time adapted to any dietary differences, such as palatability and texture, this constancy of intake of isocaloric diets conforms to the findings of Brobeck (1960) that "animals eat to keep warm, and stop eating to prevent hyperthermia." This is the thermostatic hypothesis of food intake. It does not distinguish between specific dynamic action (SDA) and the heat resulting from the oxidation of substrates in the tissues. Different diets could have significantly different SDA. This, as pointed out by Baumgardt (1969), could explain apparent errors in caloric regulation on some diets. Apart from C(Can)-SBM(Can) and C(Nig)-PNM(Nig) which had significantly higher ($P \leq 0.01$) digestible N percentage than GC(Nig)-SBM(Can), other diets were not significantly different in this parameter.

Sibbald et al (1956) have suggested that for each food N level, there is an optimum digestible energy (DE) level, when N retention is the criterion of measurement. Furthermore, this optimum DE level varies according to the quality and availability of the N source and with the species and the stage of growth of the animal consuming the food. In

the present study, there were no significant differences ($P \leq 0.01$) between diets in the various energy criteria (DE%, ME%, DE/day, ME/day), but the daily N retention was significantly lower ($P \leq 0.05$) in rats receiving GC(Nig)-SBM(Nig) diet compared, for example, with C(Can)-SBM(Can). On the other hand, the rats on this diet though not significantly different in liveweight from those on the other SBM diets were more advanced in growth than any of the others in the whole experiment. This agrees with the findings of Sibbald et al (1956) that the diet and the stage of growth influence N retention. It would therefore appear that biologically there is a point of diminishing returns in the growth of rats. The present study shows that the point of diminishing returns in daily N retention would be approached more rapidly with the GC(Nig)-SBM(Can) than with any of the other diets. This may have economic advantage where rapid production of lean is envisaged.

As noted for the entire experimental period, protein level had no significant effect ($P \leq 0.01$) on the liveweight of rats used for the digestibility and retention studies. However, it significantly but inversely modified ($P \leq 0.01$) N retention percentage and the percentage DN retained. The lowest dietary protein level gave the highest N retention percentage and the highest percentage DN retained. The highest dietary protein level gave the lowest values for these measurements. Daily N digested by the rats on the 12% dietary protein was less ($P \leq 0.01$) than that of rats on the 16 and 20% protein diets.

Our data also show that protein levels significantly affected energy utilization. Although no significant difference was observed between 20 and 16% protein diets in the DE, ME, and ME percentages, the

12% protein diet gave higher ($p \leq 0.01$) values for these measurements. In practical situations, to derive the most from limited resources, efficient use of whatever is available is often necessary. Metabolically, the same principle seems to hold within the physiological and biochemical limits of the rat.

SUMMARY OF RESULTS AND CONCLUSIONS

Proximate and amino acid analyses revealed major differences between PNM(Nig) and SBM(Can). Crude protein and fat respectively were 50 and 6% for PNM(Nig). The corresponding values for SBM(Can) were 45.5 and 2.0%. There were no major differences between C(Nig) and C(Can) in proximate analyses. Both had about 9% crude protein and 4% crude fat against 9.0% crude protein and 3.1% crude fat for GC(Nig). Amino acid analyses [Appendix Tables iv to vi(b)] show that PNM(Nig) was considerably lower than SBM(Can) in lysine, threonine, methionine, isoleucine, valine, alanine and cystine. PNM(Nig) was much higher in arginine than SBM(Can). C(Can) was about 0.4% lower than C(Nig) and 0.2% lower than GC(Nig) in lysine.

Biological tests revealed major differences in the nutritive values of PNM(Nig) compared with SBM(Can). PNM(Nig)-supplemented diets gave significantly lower rate of gain, more fat and less lean in the carcasses than SBM(Can)-supplemented diets. Important interactions were observed between protein and energy sources. These are discussed in the text.

Overall gains on this experiment were lower than would normally be expected for weanling Sprague-Dawley rats. No explanation could be found for this, although prolonged inbreeding of the strain of rats used could be partly responsible. This colony of rats has now been discarded in the Department of Animal Science and a new strain introduced in November, 1971.

Male surpassed female rats in most of the traits measured. Protein levels had varied effects on different traits. However, of the three protein levels (20, 16 and 12%) used in this study, the optimum level appeared to be 16% when dietary energy was approximately 3,600 kcal/kg.

Supplementation of C(Can)-PNM(Nig) with DL-methionine and L-lysine to raise the levels to those of the control C(Can)-SBM(Can) diets did not improve the former.

It would be useful to perform a similar experiment with weanling pigs supplementing PNM diets with various combinations of methionine, lysine, threonine and tryptophan using isocaloric diets (approximately 3,600 kcal/kg).

Increased production of SBM in Nigeria would be of a definite advantage to its livestock production. The processing technique currently used in the production of PNM(Nig) is worth evaluating to see if changes in processing could improve the nutritive quality of PNM(Nig) without sacrificing the efficiency of oil extraction.

The present study has revealed some unexpected differences in feeding value, especially those arising from interactions between protein and energy sources. These interactions could well be exploited in practical animal production. It is desirable to extend the studies to other Nigerian foodstuffs and to widen the chemical evaluation to facilitate the interpretation of the biological data.

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Appendix Table i. Production trends of some Nigerian crops¹

		Production - 1000 metric tons Yield = 100 kg/hectare						
Crop	Production and Yield	1948- 1952	1961- 1965	1966	1967	1968	1969	1970
Maize	Production in Nigeria	644	1033*	1219	950	1181	1219F	1220F
	Yield in Nigeria	8.9	9.2	10.2	8.2	11.8	11.1F	11.1F
	Yield in North America	24.9	41.7	45.5	49.4	49.4	52.6	45.1
Sorghum	Production in Nigeria	2040F	2916	3600F	3390	3099	3500F	3500
	Yield in Nigeria	6.5	8.5	9.0F	8.5F	7.7F	8.8F	8.8F
	Yield in North America	12.6	28.3	35.0	31.6	33.2	34.7	31.8
Millet	Production in Nigeria	1760F	2692	3000F	2590	2394	2800F	2800F
	Yield in Nigeria	5.4	8.3	8.7F	8.0F	7.7F	8.2F	8.2F
	Yield in North America	-	-	-	-	-	-	-
Ground-nuts	Production in Nigeria	690*	1418*	1755*	1256*	1445*	1360*	1175*
	Yield in Nigeria	7.1F	12.1F	14.6F	11.2*	11.9*	11.6*	11.2F
	Yield in North America	9.2	15.6	19.0	19.8	19.8	19.5	23.0
Soybeans	Production in Nigeria	4.0	18.0*	15.0	16.0	12.0*	12.0*	12.0F
	Yield in Nigeria	5.3F	8.7F	8.8F	8.9F	8.6F	8.6F	8.6F
	Yield in North America	14.3	16.3	17.1	16.5	18.1	18.5	18.0
Cassava	Production in Nigeria	5800F	7247F	7500F	7400F	7200F	6800F	6800F
	Yield in Nigeria	58F	62F	63F	67F	66F	65F	68F
	Yield in North America	-	-	-	-	-	-	-
Cocoa	Production in Nigeria	1054	2150	2672	2380	1863	2103	2185
	Yield in Nigeria	-	-	-	-	-	-	-
	Yield in North America	-	-	-	-	-	-	-

¹ FAO Production Yearbook, 1970

* = Unofficial figure

F = FAO estimate

Appendix Table ii. Calculated gross composition of diets

Diet Number	Protein level(%)	* DM%	+ DE kcal/g	* Prot. %	* Fat%	* Fiber%	* Ash%	+ Ca%	+ P%
C(Can)-SBM(Can)	20	91.7	3.630	20.2	9.2	4.2	6.8	0.78	0.60
"	16	91.7	3.622	16.6	7.7	3.0	7.2	0.64	0.48
"	12	92.7	3.618	12.3	5.7	2.6	7.9	0.48	0.36
C(Nig)-SBM(Can)	20	92.6	3.630	19.8	9.4	3.7	6.4	0.78	0.60
"	16	92.8	3.622	16.3	7.9	3.2	7.1	0.64	0.48
"	12	92.9	3.618	12.3	5.6	2.7	7.7	0.48	0.36
GC(Nig)-SBM(Can)	20	92.1	3.524	20.1	7.9	3.5	6.2	0.79	0.59
"	16	92.5	3.538	15.0	6.4	2.4	6.4	0.65	0.47
"	12	92.0	3.554	12.5	4.9	2.1	8.0	0.48	0.36
C(Can)-PNM(Nig)	20	92.0	3.585	20.1	9.2	3.2	6.8	0.83	0.60
"	16	91.7	3.587	16.8	8.8	2.7	7.7	0.67	0.47
"	12	92.3	3.591	12.6	6.3	2.0	8.1	0.50	0.36
C(Nig)-PNM(Nig)	20	93.1	3.585	20.9	9.2	3.5	6.8	0.83	0.60
"	16	92.8	3.587	16.0	9.0	2.4	7.4	0.67	0.47
"	12	92.1	3.591	12.7	6.1	2.2	8.2	0.50	0.36
GC(Nig)-PNM(Nig)	20	93.4	3.473	19.8	9.0	3.3	7.0	0.83	0.59
"	16	93.0	3.498	15.7	7.2	2.7	7.8	0.68	0.47
"	12	92.8	3.524	12.2	5.5	2.1	6.2	0.50	0.36
C(Can)-PNM(Nig)-ML	20	91.9	3.585	21.0	9.0	3.3	7.2	0.83	0.60
"	16	92.0	3.587	16.6	8.8	2.6	7.7	0.67	0.47
"	12	91.6	3.591	12.4	6.3	2.3	8.3	0.50	0.36

* Based on analyses of diets.

+ Based on literature values.

Appendix Table iii(a). Protein and amino acid composition of diets

Diet	Protein level		Alanine %	Arginine	Aspartic Acid		Glutamic Acid %	Glycine %	Histidine	Iso-Leucine		Leucine %
	+	% *			%	%				%	%	
C(Can)-SBM(Can)	20	19.4	0.98	1.13	1.83	3.44	0.79	0.50	0.81	1.61		
"	16	15.5	0.79	0.91	1.46	2.75	0.63	0.40	0.65	1.28		
"	12	11.6	0.59	0.67	1.10	2.06	0.48	0.30	0.48	0.96		
C(Nig)-SBM(Can)	20	19.5	0.95	1.11	1.81	3.35	0.77	0.48	0.80	1.57		
"	16	15.6	0.76	0.89	1.44	2.68	0.62	0.39	0.64	1.25		
"	12	11.7	0.57	0.66	1.08	2.01	0.47	0.29	0.48	0.94		
GC(Nig)-SBM(Can)	20	19.3	0.98	1.09	1.81	3.35	0.76	0.47	0.81	1.53		
"	16	15.5	0.78	0.88	1.44	2.68	0.61	0.37	0.65	1.22		
"	12	11.6	0.59	0.65	1.08	2.01	0.46	0.28	0.48	0.92		
C(Can)-PNM(Nig)	20	20.1	0.94	1.72	1.92	3.76	1.01	0.47	0.66	1.49		
"	16	16.1	0.75	1.37	1.53	3.01	0.80	0.38	0.52	1.20		
"	12	12.1	0.56	1.03	1.15	2.25	0.60	0.28	0.40	0.89		
C(Nig)-PNM(Nig)	20	20.2	0.91	1.70	1.89	3.66	0.99	0.45	0.65	1.45		
"	16	16.2	0.73	1.36	1.51	2.93	0.79	0.36	0.51	1.16		
"	12	12.1	0.54	1.02	1.13	2.20	0.59	0.27	0.39	0.87		
GC(Nig)-PNM(Nig)	20	20.0	0.94	1.68	1.89	3.66	0.98	0.43	0.66	1.41		
"	16	16.0	0.75	1.35	1.51	2.93	0.77	0.35	0.52	1.13		
"	12	12.0	0.56	1.01	1.13	2.20	0.58	0.26	0.40	0.84		
C(Can)-PNM(Nig)-ML	20	20.1	0.94	1.72	1.92	3.76	1.01	0.47	0.66	1.49		
"	16	16.1	0.75	1.37	1.53	3.01	0.80	0.38	0.52	1.20		
"	12	12.1	0.56	1.03	1.15	2.25	0.60	0.28	0.40	0.89		

+ Estimated

* Determined

Appendix Table iii(b). Amino acid composition of diets - Continued

Diets	Protein Level %	Lysine %	Methionine -Cystine %	Phenyla- lanine %	Proline %	Serine %	Threonine %	Tyrosine %	Valine %	Ammonia %
	+									
C(Can)-SBM(Can)	20	0.98	0.67	0.89	1.12	0.93	0.70	0.55	0.90	0.39
"	16	0.78	0.54	0.71	0.90	0.75	0.57	0.44	0.72	0.32
"	12	0.59	0.40	0.54	0.67	0.56	0.42	0.33	0.54	0.23
C(Nig)-SBM(Can)	20	1.01	0.65	0.87	1.08	0.92	0.69	0.53	0.89	0.39
"	16	0.80	0.53	0.70	0.86	0.73	0.56	0.43	0.70	0.31
"	12	0.61	0.39	0.53	0.65	0.55	0.42	0.32	0.53	0.23
GC(Nig)-SBM(Can)	20	0.99	0.63	0.87	1.05	0.89	0.67	0.51	0.88	0.39
"	16	0.79	0.51	0.70	0.84	0.71	0.54	0.41	0.70	0.32
"	12	0.60	0.38	0.53	0.63	0.53	0.40	0.31	0.53	0.23
C(Can)-PNM(Nig)	20	0.59	0.57	0.92	1.03	0.92	0.55	0.59	0.82	0.44
"	16	0.46	0.46	0.73	0.82	0.74	0.44	0.46	0.66	0.35
"	12	0.35	0.34	0.55	0.62	0.55	0.33	0.35	0.49	0.27
C(Nig)-PNM(Nig)	20	0.61	0.55	0.90	0.98	0.90	0.54	0.57	0.80	0.43
"	16	0.49	0.44	0.72	0.78	0.72	0.42	0.45	0.64	0.35
"	12	0.37	0.33	0.54	0.59	0.54	0.32	0.34	0.48	0.26
GC(Nig)-PNM(Nig)	20	0.60	0.53	0.90	0.95	0.87	0.52	0.55	0.79	0.44
"	16	0.47	0.42	0.72	0.75	0.70	0.41	0.43	0.64	0.35
"	12	0.36	0.30	0.54	0.57	0.52	0.31	0.33	0.47	0.27
C(Can)-PNM(Nig)-ML	20	0.59	0.57	0.92	1.03	0.92	0.55	0.59	0.82	0.44
"	16	0.46	0.46	0.73	0.82	0.74	0.44	0.46	0.66	0.35
"	12	0.35	0.34	0.55	0.62	0.55	0.33	0.35	0.49	0.27

+ Estimated

Appendix Table iv. Protein and amino acid percentages of food ingredients

Food Ingredients	Protein %	Alanine %	Arginine %	Aspartic		Glutamic		Glycine %	Histidine %	Iso- Leucine %	Leucine %
				Acid %	Cystine %	Acid %					
Corn(Can)	9.1	0.70	0.39	0.59	0.19	1.77		0.34	0.26	0.32	1.11
Corn(Nig)	9.3	0.64	0.35	0.54	0.18	1.60		0.31	0.22	0.30	1.04
Guinea Corn(Nig)	9.0	0.69	0.33	0.54	0.17	1.60		0.28	0.23	0.32	0.97
SBM(Can)	43.5	1.82	2.75	4.53	0.92	7.45		1.82	1.07	1.90	3.04
PNM(Nig)	50.1	1.83	5.01	5.30	0.82	9.23		2.72	1.07	1.59	2.91

Food Ingredients	Lysine %	Methionine %	Phenyla- lanine %	Proline %	Serine %	Threonine %	Tyrosine %	Valine %	Ammonia %
Corn(Can)	0.19	0.17	0.43	0.80	0.44	0.33	0.28	0.44	0.23
Corn(Nig)	0.24	0.14	0.40	0.71	0.41	0.30	0.25	0.41	0.22
Guinea Corn(Nig)	0.21	0.11	0.40	0.66	0.36	0.26	0.21	0.40	0.23
SBM(Can)	2.62	0.52	1.97	2.08	2.08	1.59	1.19	1.99	0.81
PNM(Nig)	1.59	0.42	2.26	1.92	2.24	1.22	1.43	1.91	1.03

Appendix Table v. Amino acid percentages of proteins of food ingredients (as fed basis)

Food Ingredients	Protein %	Alanine %	Arginine %	Aspartic Acid %		Cystine %	Glutamic Acid %		Glycine %	Histidine %	Iso-Leucine %	
Corn(Can)	9.1	7.72	4.33	6.44	2.04	19.44	3.73	2.85	3.57	12.25		
Corn(Nig)	9.3	6.92	3.79	5.82	1.90	17.23	3.32	2.46	3.19	11.14		
Guinea Corn(Nig)	9.0	7.73	3.70	6.01	1.84	17.77	3.11	2.26	3.61	10.79		
SBM(Can)	43.5	4.19	6.34	10.43	2.12	17.14	4.20	2.45	4.37	6.98		
PNM(Nig)	50.1	3.66	10.01	10.58	1.63	18.42	5.43	2.14	3.18	5.81		

Food Ingredients	Lysine %	Methionine %	Phenylalanine %	Proline %	Serine %	Threonine %	Tyrosine %	Valine %	Ammonia %
Corn(Can)	2.10	1.87	4.75	8.82	4.89	3.61	3.06	4.86	2.58
Corn(Nig)	2.58	1.50	4.25	7.62	4.39	3.26	2.65	4.39	2.35
Guinea Corn(Nig)	2.33	1.28	4.40	7.33	3.96	2.89	2.29	4.49	2.56
SBM(Can)	6.02	1.21	4.53	4.80	4.80	3.67	2.74	4.58	1.85
PNM(Nig)	3.16	0.85	4.52	3.83	4.47	2.44	2.85	3.81	2.07

Appendix Table vi. Amino acid percentages of proteins of food ingredients (fat-free basis)

Food Ingredients	Protein %	Alanine %	Arginine %	Aspartic Acid		Glutamic Acid		Glycine %	Histidine %	Iso-Leucine %		Leucine %
				Acid %	Cystine %	Acid %	%					
Corn(Can)	10.0	8.04	4.51	6.71	2.13	20.25		3.89	2.97	3.72		12.76
Corn(Nig)	10.4	7.22	3.96	6.08	1.98	17.99		3.47	2.57	3.33		11.63
Guinea Corn(Nig)	9.6	7.98	3.82	6.20	1.90	18.34		3.21	2.33	3.73		11.13
SBM(Can)	47.6	4.27	6.46	10.63	2.16	17.47		4.28	2.50	4.45		7.12
PNM(Nig)	52.3	3.90	10.66	11.27	1.74	19.62		5.78	2.28	3.39		6.19

Food Ingredients	Lysine %	Methionine %	Phenylalanine %	Proline %	Serine %	Threonine %	Tyrosine %	Valine %	Ammonia %
Corn(Can)	2.19	1.95	4.95	9.19	5.09	3.76	3.19	5.06	2.69
Corn(Nig)	2.69	1.57	4.44	7.95	4.58	3.40	2.77	4.58	2.45
Guinea Corn(Nig)	2.40	1.32	4.54	7.56	4.09	2.98	2.36	4.63	2.64
SBM(Can)	6.14	1.23	4.62	4.89	4.89	3.74	2.79	4.67	1.89
PNM(Nig)	3.37	0.90	4.81	4.08	4.76	2.60	3.04	4.06	2.20

Appendix Table vii(a). Mean squares: Gain, food consumption and efficiency of food conversion data

Factors	df	Liveweight Gain (Weekly)	Food Cons. (Weekly)	Gain/Food (Weekly)
W	3	456.46	5779.7	0.22332
S	1	117.86	992.23	0.11031E-02
WS	3	59.574	17.307	0.55330E-02
P	2	23.813	51.364	0.24796E-01
WP	6	127.11	183.75	0.31207E-01
SP	2	8.3958	9.7584	0.12053E-01
R	6	186.51	333.55	0.36759E-01
WR	18	30.695	89.574	0.22657E-01
SR	6	19.485	211.75	0.76690E-02
PR	12	20.174	238.83	0.82754E-02
3 factor interactions or higher*				
ERROR	168	16.896	138.74	0.10388E-01
TOTAL	335			

* Although three factor and higher interactions were calculated, they are not presented here.

Statistical analyses were conducted on a weekly as well as cumulative basis but the weekly data are not discussed in the text.

Appendix Table vii(b). Mean squares: Gain, food consumption and efficiency of food conversion data - Continued

Factors	df	Liveweight Gain (Cum)	Food Cons. (Cum)	Gain/Food** (Cum)	Empty Body Wt. Gain	Empty Body Wt. Gain/Food	DM Gain	DM Gain/Food**
S	1	471.4	3968.9	0.14310E-02	676.60	0.32476E-02	1.4800	0.92400E-04
P	2	95.250	205.46	0.20685E-02	67.033	0.12461E-02	18.999	0.24109E-03
SP	2	33.583	39.034	0.42691E-03	10.444	0.99594E-04	1.6950	0.21636E-04
R	6	746.03	1334.2	0.83087E-02	571.56	0.64680E-02	57.722	0.56994E-03
SR	6	77.940	847.01	0.33483E-02	57.903	0.29248E-03	7.6516	0.47717E-04
PR	12	80.694	955.33	0.43139E-03	71.380	0.43960E-03	12.115	0.79565E-04
3 factor interaction or higher*								
ERROR	42	42.869	1097.2	0.24593E-03	38.669	0.24373E-03	5.4457	0.54337E-04
TOTAL	83							

* Although three factor and higher interactions were calculated, they are not presented here.

** The analyses were conducted on gain (g)/food (g) but the discussion in the text is based on the reciprocal of this calculation, i.e. food (g)/gain (g).

Appendix Table viii. Mean squares: Carcass analyses

Factors	df	Carcass			Carcass PM%	GE from		GE from Carcass Prot.	GE in Whole Carcass	Carcass N		EBW Liveweight
		Prot.%	Fat%	Ash%		Carcass Fat	Carcass Fat			N ret.	%	
R	6	57.449	46.523	0.15684	6.7280	223.19	223.19	1151.8	1670.6	0.15390E-08		3.3486
S	1	101.97	112.75	0.30360	37.387	764.72	764.72	101.77	59.573	42.857		50.329
RS	6	7.7449	7.6791	0.17576	0.74117	41.272	41.272	452.07	222.69	41.873		2.8376
P	2	381.46	452.30	5.1887	22.865	3609.7	3609.7	836.42	1857.9	637.23		30.875
RP	12	8.2238	10.210	0.31040	2.4337	171.66	171.66	253.28	510.89	20.180		1.4114
SP	2	30.536	30.673	0.48900	0.59867	279.26	279.26	111.21	179.34	5.8214		5.9184
3 factor interactions* or higher												
ERROR	42	8.5944	9.8181	0.33948	1.8247	133.63	133.63	315.51	465.43	27.786		3.5759
TOTAL	83											

* Although three factor and higher interactions were calculated, they are not presented here.

Appendix Table ix. Mean squares: Energy and N digestion and retention

Factor	df	Wt. of Rat	Av. Daily Food	DN%	N.Ret.%	N.ret./DN%	Daily N Dig. in GMS	Daily N ret. GMS	DE%
R	6	573.56	3.3599	31.719	174.45	202.31	0.19111E-02	0.15262E-02	4.4721
P	2	69.232	1.4695	5.5376	469.92	763.41	0.32088E-01	0.25452E-02	95.896
RP	12	49.204	2.5390	11.710	72.961	105.30	0.15492E-02	0.87857E-03	3.0325
ERROR	21	114.64	1.1281	12.348	76.247	94.792	0.74047E-03	0.54524E-03	3.7100
TOTAL	41								

ME%	ME _n %	DE/Day	ME/Day
8.1291	15.545	30.203	27.744
144.81	184.61	20.103	20.592
3.0979	3.5076	20.618	20.489
4.2024	5.5373	15.357	13.826

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